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Mitigating Flooding in Khlong Toei

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Mitigating the Effects of Flooding in the Khlong Toei Slum of Bangkok, Thailand

Khlong Toei, Bangkok, Thailand

Sponsored by the Duang Prateep Foundation

March 1st, 2017

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Abstract

In Bangkok, Thailand, torrential downpours during monsoon season lead to flooding in the Khlong Toei slum, which prompts many health and sanitation concerns. We identified the key infrastructural contributors to flooding and created a collection of geographical maps based on our interviews, observations, and measurements in order to convey to external stakeholders the susceptibility of certain areas within the slum. Additionally, we formulated a series of recommendations to improve the waste management practices and the drainage infrastructure within the slum.

Executive Summary

Introduction and Background

One quarter of the world's urban population lives in slums, the most deprived and isolated form of informal settlement, where occupants have no right to the land. Often, slum residents suffer disproportionately to natural disasters because the only affordable land is located in highly undesirable areas. This relationship between poverty, location, and the environment is referred to as "environmental justice" (Habitat iii, 2016). The most common and pervasive problems in slum communities often include improper sanitation, lack of infrastructure for drainage and waste removal, lack of adequate housing, and increased exposure to environmental threats such as flooding, monsoons, and volatile weather (Informal Settlements, 2015).

Our project focused specifically on the Khlong Toei slum in Bangkok, Thailand. The slum is made up of three communities: Locks 1-2-3, Locks 4-5-6, and 70 Rai.

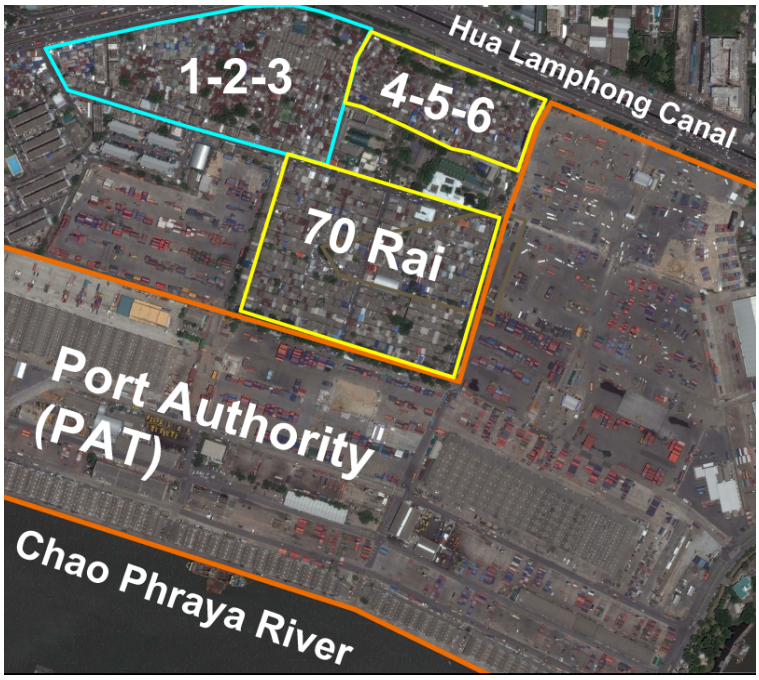

Figure A: Aerial Road Map of Khlong Toei

Located on a plot of land owned by the Port Authority of Thailand (PAT), the community is built over swampland and thus experiences frequent floods, especially during the Southwest and Northeast monsoons (Drakakis-Smith, 2012). Standing water resulting from such flooding acts as a breeding ground for mosquitoes and causes many health problems for the community (Pii Fay, personal communication, 12 January 2017). The sponsor we worked with during our project was the Duang Prateep Foundation (DPF), a non-profit organization that aims to address five overarching issues in the slum: education, health, social services, human development, and emergency funding (Murray, 2007). One of the best ways to assist the DPF in helping the community is to provide tangible information the DPF can use to convey the flooding problem to key stakeholders.

Goal, Objectives, and Methodology

The goal of our project was to convey vulnerabilities to flooding within the Khlong Toei slum of Bangkok, Thailand in order to enable the DPF to bring about change, which will ultimately mitigate the effects of flooding within the community. In order to accomplish this goal, we divided our research into four objectives:

1. Analyze the physical attributes of the slum in order to understand the vulnerability to flooding in Khlong Toei.

In order to gain understanding of Khlong Toei's current state of flooding, we visited the slum, performed interviews with Khlong Toei residents, community leaders, and Duang Prateep Foundation officials, and took measurements within the slum's walkways. The attributes we recorded were the elevation, trash buildup in drains, water flow, depth of the drains, and depth of standing water.

2. Investigate the social factors that are inhibiting progress towards flooding solutions.

Our group interviewed many of the key stakeholders whose roles play into the mitigation of flooding in Khlong Toei. We first spoke with the Kru Prateep (leader of the DPF), and community leaders to begin to understand the relationship between different parties which affect flooding in the slum. Later on we interviewed representatives from the PAT, Pavarich Meebangsai of the Khlong Toei District Department of Drainage and Sewage, and Dr. Sopon Pornchokchai, a local researcher of slums to figure out what is preventing the community from solving the flooding problem.

3. Develop visualization tools displaying both notable contributors to flooding and areas that are most vulnerable to flooding.

After gathering substantial data regarding the physical infrastructure present in the slum, we used a software called QGIS to generate maps of the community depicting the most susceptible areas to flooding based off of the attributes described in Objective 1. Visualizing this data and overlaying maps allowed us to see many trends and correlations affecting flooding that were not immediately obvious.

4. Identify feasible solutions to be implemented by the DPF in conjunction with the Port Authority of Thailand and the Khlong Toei District Office for long-term flooding mitigation in the Khlong Toei slum.

In order to further help the DPF explain flooding in the slum to stakeholders, we developed an action plan timeline outlining our recommendations for the DPF. We prioritized recommendations that could feasibly be implemented before the monsoon season in May, and also provided long-term strategies.

Results and Findings

After analyzing the data we collected, we were able to organize our findings into three different categories: the current state of drainage in Khlong Toei, the major contributors to flooding,

and the relationships between key stakeholders. We have highlighted the key findings in each of these areas below.

Finding: Failing drainage systems lead to flooding in Khlong Toei.

From our interviews and first-hand inspection, we found that water located in the drainage trenches situated along the sides of the walkways is predominantly stagnant and is pooling due to clogging. During periods of intense rainfall, rainwater adds to the volume of this standing water and flooding occurs. Shown below is an example of one of the clogged drainage trenches preventing water flow in the Khlong Toei slum.

Figure B: Trash Buildup in the Drains Preventing Water Flow

Finding: Lower lying areas in Khlong Toei are more susceptible to flooding because water flow brings trash and sediment, which clogs the drains.

We found that the areas of lower elevation in the slum tend to be where trash builds up. This is because as water flows toward locations of lower elevation, it brings with it trash and sediment which clog the drains. This decreases the effective depth of the drains and makes these areas more likely to flood when it rains. Seen below are maps of both the elevation as well as the trash buildup in both 70 Rai and Locks 4-5.

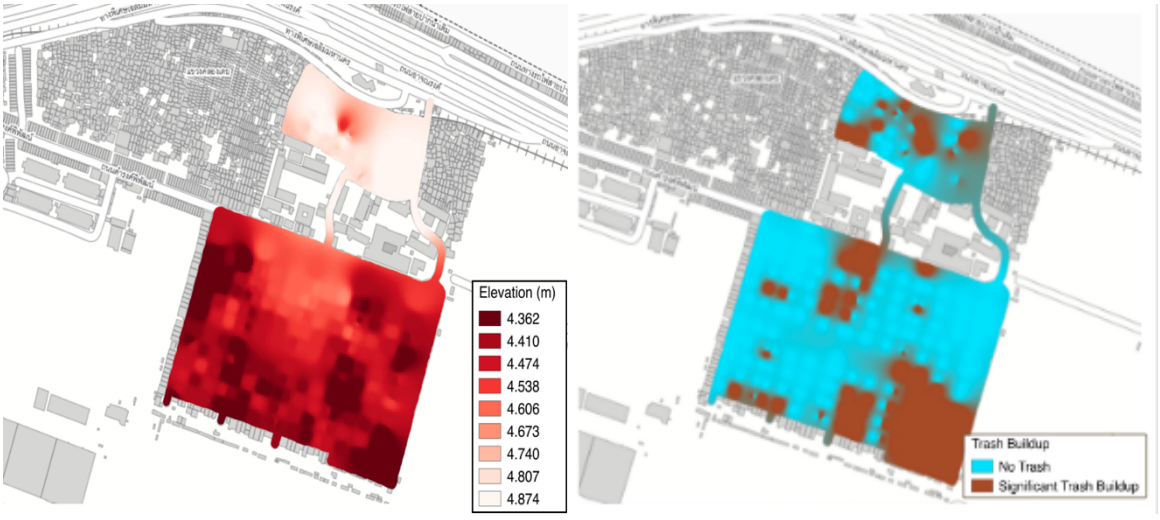

Figure C: Map of Elevation (Left) and Areas of Trash Buildup (Right)

Finding: The water from Khlong Toei cannot be released to the Chao Phraya River due to the water quality.

We collected water from 70 Rai and submitted it to the Environmental Research Institute at Chulalongkorn University. We compared the results with the acceptable water quality based on the Pollution Control Department of Thailand and found the water quality in the southeast corner of 70 Rai does not meet the standard, and therefore cannot be released directly into the Chao Phraya River. Until the water quality is improved, the drainage infrastructure problem leading to flooding will continue to persist in Khlong Toei.

Finding: Many residents of Khlong Toei lack motivation to improve their quality of living.

The residents believe they will be evicted in the near future and thus have very little motivation to improve their current living situation. Additionally, they do not own the land and believe action should be taken not by themselves, but by the landowner (the PAT). This attitude makes it very difficult for programs to gain traction and be sustained, as the residents have trouble committing to community efforts.

Recommendations

Following from our findings, we outlined recommendations for key stakeholders in the Khlong Toei community to begin mitigating flooding. Below we have highlighted three of the most important.

Recommendation: Residents add new drainage channels to Locks 4-5

The residents of Khlong Toei installed a new pipe in the northern part of Locks 1-2-3, which connected to the Bangkok Metropolitan Drainage System and allowed water to flow directly into the canal to the north instead of all the way down through 70 Rai. We recommend the residents install similar additional drainage infrastructure in certain locations in Locks 4-5. The first map of Locks 4-5 shown below outlines in red the most susceptible areas to flooding in Locks 4-5, as well as the current formal drainage system in green. The second map lays out our recommended drainage system plan, which targets the most susceptible areas. Shown in orange are the most essential drains, while those in yellow are less necessary but would be useful with more time and resources. The blue arrows dictate water flow.

Figure D: Map of Susceptibility (Left) and Suggested Drainage Plan (Right)

Recommendation: Community leaders establish recurring drainage community cleaning days with Khlong Toei District.

The Khlong Toei District occasionally helps residents of the slum clean the drainage system by providing labor and materials. In the past, the District and community leaders struggled to schedule a time together because the residents are typically working their day jobs when the District is available. We are recommending both parties plan recurring community cleaning days on holidays such as Mother's day, Father's day, and certain national Buddhist holidays when both parties are available.

Recommendation: The DPF and community leaders establish waste management initiatives with the residents.

After finding that areas of trash buildup are strongly correlated with the most flood-prone areas in the slum, we recommend the DPF and community leaders initiate and lead the formation of waste management programs that incentivize the residents to clean using some sort of exchange reward. Successful programs in the past included "Garbage for Eggs" and "Trash for Toothpaste" where residents traded garbage for eggs or toothpaste, respectively.

Conclusion

Flooding in Khlong Toei remains a serious problem that affects the daily lives and health of the residents of the community. To try to further the progress towards a sustainable, feasible solution our team constructed a collection of maps depicting many factors surrounding the state of flooding in Khlong Toei in order to help the DPF advocate for the slum to external stakeholders. Additionally, we devised an action plan consisting of a series of recommendations for the DPF to begin implementing before the monsoon season. We hope our recommendations, along with our deliverables, will help the DPF begin to mitigate flooding in the Khlong Toei slum.

Acknowledgements

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Authorship

All members of the project team edited all parts of this Report

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Chapter 1: Introduction

One quarter of the world's urban population lives in slums, the most deprived and isolated form of informal settlement, where occupants have no right to the land. These people are referred to as "squatters" and they typically experience extremely harsh living conditions due to their low socioeconomic status and lack of support from government and local authorities (Habitat iii, 2016). Often, slum residents suffer disproportionately from natural disasters because the only affordable land is located in highly undesirable areas. This relationship between poverty, location, and the environment is referred to as "environmental justice" (Habitat iii, 2016). Residents of informal settlements are vulnerable to a variety of threats because of their socioeconomic status. The most common and pervasive problems in slum communities often include improper sanitation, lack of infrastructure for drainage and waste removal, lack of adequate housing, and increased exposure to environmental threats such as flooding, monsoons, and volatile weather (Informal Settlements, 2015).

One such informal settlement is the slum in the Khlong Toei district of Bangkok, Thailand. Located on a plot of land owned by the Port Authority of Thailand, the community is built over swampland and thus experiences frequent floods, especially during the Southwest and Northeast monsoons (Drakakis-Smith, 2012). Standing water resulting from flooding acts as a breeding ground for mosquitoes and causes many health problems for the community (Fai, personal communication, 12 January 2017). The diseases resulting from this are especially challenging due to limited physical and financial access to health services within the slum. Khlong Toei residents are also highly vulnerable from a political and socioeconomic perspective. Their income level is only a small fraction of the average household in Bangkok and is not enough to afford rights to the land on which they live (Sapsuwan, 2014). Because they live on informal land without a title, many residents are ineligible for government aid such as health and waste management services and the Port Authority has actively campaigned for its removal through multiple eviction efforts (Drakakis-Smith, 2012).

One organization working to aid the Khlong Toei community is our sponsor, the Duang Prateep Foundation. The Foundation began as a grade school that children of the slum could attend and has grown into an organization utilizing the work of more than 100 full-time volunteers and employees and reaching out to more than 100,000 residents of the Khlong Toei community (Schneider, 2005). This non-profit aims to address five overarching issues in the slum that the organization believes to be the most pressing: education, health, social services, human development, and emergency funding (Murray, 2007). With more than 20 active projects, the DPF has worked on topics such as special schools for the hearing impaired, youth and young women's development, senior citizen's welfare, and sexual safety — in fact, the DPF's AIDS awareness campaign is the leading sexual health program in all of Thailand (Murray, 2007). While the Foundation has had great success in helping the residents of Khlong Toei, it continues to look for more ways to make the community less vulnerable.

The ultimate goal of this project was to convey vulnerabilities to flooding within the Khlong Toei slum of Bangkok, Thailand in order to enable the Duang Prateep Foundation to bring about change that will ultimately mitigate the effects of flooding within community. To achieve this goal, we first needed to analyze the physical attributes of the slum in order to understand the vulnerability to flooding faced by the residents of Khlong Toei. Second, we needed to investigate the social factors that are inhibiting progress towards flooding solutions. Next, we developed visualization tools to display both notable contributors to flooding and areas most vulnerable to flooding in order

to assist the Duang Prateep Foundation in explaining the current state of susceptibility to flooding in Khlong Toei to policy makers. Finally, we identified feasible solutions to be implemented by the Duang Prateep Foundation in conjunction with the Port Authority of Thailand and the Khlong Toei District Office for long term flooding mitigation in the Khlong Toei slum. The following chapters will inform the reader of background information pertaining to Khlong Toei and its vulnerability, outline the methodology used for our research and mapping processes, explain the results we collected and the visualization tools we developed, and make suggestions for the use and continuation of this project.

Chapter 2: Background

Informal settlements are communities that develop with little to no planning by people who cannot afford proper housing. These communities often arise in urban centers where economic growth shows opportunity for those trapped in poverty elsewhere. The following sections discuss the social and economic issues faced by residents of informal settlements, the infrastructural issues within these settlements, and the environmental contributors to flooding within these communities.

2.1 Social and Economic Issues of Informal Settlements

Informal settlements, especially slums, which are the most deprived and excluded form of informal settlement (Habitat iii, 2015), are often perceived to be hubs of poverty. Many people fail to recognize that slums are not only hubs of poverty, but they also perpetuate the cycle of poverty, making it difficult for community members to break free of their economic vulnerability. UN-Habitat, a United Nations program, states in its Global Report on Human Settlements that income or capability poverty is considered "a cause (and to a large extent, a consequence) of slum conditions" (The Challenge, 2003, p.14). Many residents of informal settlements, especially those in slums, are extremely poor and often struggle with unemployment or underemployment. Many slum residents who find employment find it in informal or slum-based jobs, which are "characterized by less job security, lower incomes, an absence of access to a range of social benefits, and fewer possibilities to participate in formal education and training programs" (Clos, 2014). For some, living in a slum is a temporary stepping-stone towards living and working in a formal, urban environment, but many become stuck in a poverty trap that they are economically unable to leave. A case study of Bangkok slums reported that nearly 60% of the population currently living in slums were born there (The Challenge, 2003). Without a means to elevate themselves financially out of the slums, generations of people are trapped in poverty and substandard living conditions.

Furthering the cycle of poverty, many governments are unwilling to help these communities due to the high percentage of squatters living within them. The residents' squatter status leads to a complex and difficult legal situation regarding the relationship between slum residents and the authorities who own the land. This is especially important when trying to create change in the slum on a political level. The squatters are under constant pressure of being evicted, and this is why the state appears hostile towards squatters (Kim, 2010). Authorities will refuse to help when the squatters ask because they know that the people residing do not have rights to the land. While there are many organizations that attempt to encourage squatters to improve their living situations, governments can often hinder progress. The Hong Kong government, for example, actively fights against the progression of informal settlements and prevents squatters from improving their homes (Smart, 2002). While informal settlements continue to have problems that residents cannot handle on their own, governments often refuse to help, thus making the residents much more vulnerable to challenges like flooding.

Despite the perpetuation of poverty and lack of government aid, many slums are still growing (Issue paper 22 - informal settlements, 2015). In the world's poorest regions during the last 50 years, many people considered rural poor have moved to cities with the hope of a better life (UN-Habitat, 2003). Without initial capital to pay for housing within the city, many of these people find themselves forced to live in a nearby slum, within which they are subjected to a cycle poverty and substandard living conditions.

2.2 Infrastructural Setting in Informal Settlements

The property those in poverty inhabit is often land unwanted by others because it is poorly suited to support a community (Parker, 2006). In the Neza-Chalco-Itza slums in Mexico City, Mexico, for example, the land is so steep it is barely traversable and thus poses a continual threat of landslides in major storms (Connolly, 2003). In the Maili Saba slum of Nairobi, Kenya, houses are crowded so closely to the river that violent water flow caused by heavy rains often causes homes to wash away completely (Unjust Waters, 2008).

Because they often have very little income, slum residents living in such precarious geographical situations must turn to whatever materials are most readily available for building their homes. The materials are often cheap and well below construction grade (The Challenge, 2003, p.11). Homes are built with "non-permanent materials unsuitable for housing given local conditions of climate and location" (The Challenge, 2003, p.11).

Common lack of government involvement coupled with such precarious physical status means that informal settlements seldom have access to adequate waste and sanitation services (EarthScan, 2003). "Open sewers, lack of pathways, uncontrolled dumping of waste, polluted environments, etc." become common characteristic of such communities (EarthScan, 2003, p. 11). Zurbrugg found that currently one to two thirds of solid waste generated in urban centers in low-income countries of Asia is not collected. According to the UN-Habitat, less than one third of the population in most urban centers in Africa, Asia, and Latin America have access to adequate sanitary services (EarthScan, 2003). Furthermore, "perhaps as many as 100 million urban dwellers have to defecate in open spaces or into waste paper or plastic bags ('wrap and throw') because there are no toilets in their homes and public toilets are not available, are too distant, or are too expensive" (UN-Habitat, 2003, pg. xvii) In an effort to remedy this lack of infrastructure, many slum residents have dug holes in or near their homes to be used as latrines and for waste disposal (UN-Habitat, 2003). If these makeshift accommodations were connected to formal drainage systems, such plans would be effective and appropriate. However, most informal settlements lack standard waste and storm water management, which means that organic waste creates a cesspool constantly surrounding these residents (Taş et al., 2013).

Such a precarious physical situation, lack of housing, lack of drainage and sanitation that continually face these residents creates a situation where these residents are disproportionately vulnerable to suffer from natural disasters. This phenomenon is known as environmental injustice. This means that these residents are the first to be affected when environmental threats begin to emerge.

2.3 Environmental Contributors to Flooding

The likelihood of such natural disasters is increasing due to trends in climate change (earthobservatory). Climate change on a global scale is one of the largest contributors to flooding vulnerability. In 2011, four tropical storms combined with heavy and extended monsoon rains caused severe damage in Thailand, Cambodia, the Philippines, Vietnam, Laos, and Burma. In Thailand alone, there were an estimated 567 fatalities as a result. These recent flooding catastrophes in Southeast Asia can be traced to a few different factors including typhoons, heavy rains, and tropical storms (Torti, 2012). Heavy monsoon rains, typhoons, and tropical storms are a result of a larger climate change issue. Southeast Asia is especially vulnerable to the negative effects of climate change because of its rapidly growing population, (Torti, 2012). Climate change is directly linked to more intense rains, heat waves, extreme weather events, greater climate variability, and rising sea

levels. All of these factors contribute to an increased frequency and intensity of flooding (Torti, 2012).

The Fourth Assessment Report of the Intergovernmental Panel on Climate Change projected that global sea level will rise by 60cm by the year 2100 because of ocean warming and glacial melting. More recently however, decline of polar ice sheet mass has raised the height of possible sea level rise to 1m or more by 2100 (Nicholls, 2010). The effect of these physical changes have numerous direct and indirect impacts. In addition to the immediate problem of flooding, longer-term problems such as erosion and saltwater intrusion into groundwater begin to emerge as the land adapts to the new conditions (Nicholls, 2010).

While global climate trends are strong influencers of sea-level rise, local and human-induced changes can play an even larger role for certain coastal cities. Studies show that "The most dramatic subsidence effects have been caused by drainage and groundwater fluid withdrawal; over the 20th century, coasts have subsided by up to 5m in Tokyo, 3m in Shanghai, and 2m in Bangkok" (Nicholls, 2010). Subsidence, the geological process of land sinking is the underlying cause of this relative sea-level rise that is actually rising faster than climate-induced trends. In these places, overdrawing the water table causes land to sink by decreasing the amount of groundwater able to support structures built upon it. Many countries in South, Southeast, and East Asia are highly threatened because of the high frequency of densely populated deltas, which are often associated with large growing cities. The graphic below depicts the most vulnerable areas to coastal flooding resulting from relative and climate-induced sea-level rise (Fig.1) (Nicholls, 2010). Of these areas, the locations at highest risk are the coastal zones with dense populations, low elevations, substantial subsidence rates, and/or inadequate adaptive capacity (Nicholls, 2010).

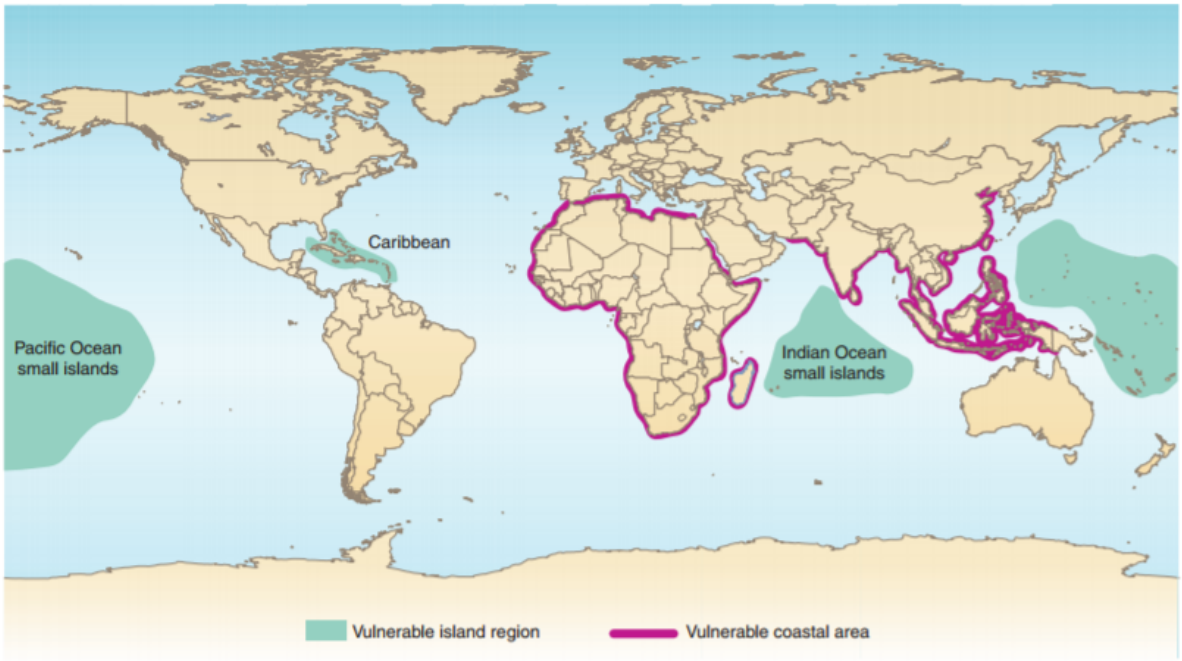

Fig. 2.1: Global Map of Vulnerable Coastal Areas (Nicholls, 2010)

The Gulf of Thailand is no exception to these trends. In this region, the sea level has been steadily rising at a rate of about 5mm/yr. for the past 25 years (Sojisuporn, 2013). Additionally, land subsidence at river mouths and coastal ports plays a major role in the recorded rising sea level. These

trends and findings are a warning that the shores of Thailand may face severe coastal recession in the near future, thus resulting in drastic increases of flooding if something is not done to slow down land subsidence (Sojisuporn, 2013). For susceptible low lying communities in coastal zones of Thailand, such as the Khlong Toei slum in Bangkok, these trends are particularly frightening.

2.4 Background Summary

Informal settlements across the globe suffer severely from environmental disasters like flooding. Because these communities are unable to receive the help they need, they are especially vulnerable. The slum of Khlong Toei shares the qualities of slums around the world that make it particularly susceptible to flooding. It is located on a plot of swampland beside the Chao Phraya River in Bangkok Thailand, has a population of over 100,000 people, and an average income that is one-third of the average in the rest of the city. By researching slums around the world, we were able understand the situation more clearly in Khlong Toei, and provide feasible solutions to the residents in developing flooding solutions.

Our sponsor was the Duang Prateep Foundation. Founded by Kru Prateep Ungsangtham Hata, the organization has grown from a small school to a prominent figure within the community. Due to their close relationship with the residents, the Duang Prateep Foundation has become the voice of the people when addressing the most prominent issues dominating the slum to authorities. As flooding conditions have worsened over recent years, the Duang Prateep Foundation asked us to assist them in developing solutions to this imminent problem.

Chapter 3: Methodology

The goal of this project was to convey vulnerabilities to flooding within the Khlong Toei slum of Bangkok, Thailand, in order to enable the Duang Prateep Foundation to bring about change that will ultimately mitigate the effects of flooding within the community. In order to realize this goal, we adopted four objectives. They are:

1. Analyze the physical attributes of the slum in order to understand the vulnerability to flooding in Khlong Toei.
2. Investigate the social factors that are inhibiting flooding solutions.
3. Develop visualization tools displaying both notable contributors to flooding and areas most vulnerable to flooding.
4. Identify feasible solutions to be implemented by the Duang Prateep Foundation in conjunction with the Port Authority of Thailand and the Khlong Toei District Office for long term flooding mitigation in the Khlong Toei slum.

3.1 Objective 1: Analyze the physical attributes of the slum in order to understand the vulnerability to flooding in Khlong Toei.

In order to fully understand what infrastructural factors are the most important for the Duang Prateep Foundation to address, we first had to develop a method that would allow us to analyze the attributes in an organized way. We decided that measuring the following would give us the best understanding of the current state of Khlong Toei's infrastructure: width of walkway, drain depth, height of visible water damage, height of water to walkway, areas of trash buildup, location of trash bins, direction of water flow, sediment buildup, and elevation. We both worked at our project site in Khlong Toei and used online resources to acquire these measurements.

We organized our data collecting so we could easily track where we made measurements. We organized our data by Soi (street) number, measuring each attribute at several places within the Soi. As we walked around the slum, we filled in a spreadsheet with all of the factors we measured, which we later used to portray and analyze the data.

In Khlong Toei, we used a measuring tape to measure the drain depth, width of the walkway, height of visible water damage, the height from the top of the water to the walkway, and sediment buildup. As we walked around the slum, we also marked on a map the areas of trash buildup, locations of trash bins, and direction of water flow in the drains. For us to portray this data visually, we also needed to know the longitude and latitude of each point we measured. For 70 Rai, we did this by using the Google Earth API, because the streets are visible on this map. In Locks 4-5-6, we walked through the community, using the Google Maps mobile application to find our coordinates. Using this information, we then used the Google Earth API to find the elevation of every location, and added that to the data we had previously collected.

We took these measurements in 179 locations in 70 Rai and 60 locations in Locks 4-5-6. This method of data collection and organization made it possible for us to use geographic software to analyze these attributes. This method also allowed us to keep track of the most notable areas in the slum that had experienced flooding. In Objective 3, we analyzed the data we collected using geographic software.

3.2 Objective 2: Investigate the social factors that are inhibiting flooding solutions.

Investigating the social and political factors that play into the mitigation of flooding in Khlong Toei was an important step towards the realization of our goal. We needed to understand the relationship between all parties affected by flooding in Khlong Toei. In order to achieve this, we talked to representatives from each of the major stakeholders as well as outside sources.

The first step we took to understanding the social factors was interviewing our sponsor, the Duang Prateep Foundation, Kru Prateep, it's head, and the community leaders of 70 Rai and Locks 4-5-6, residents and informal heads of the community. From these interviews, we gained an initial understanding of the specific problem as well as the social relationships, which we further analyzed. A copy of our interview questions for the Duang Prateep Foundation and Kru Prateep can be found in Appendix A.

We then performed interviews with Khlong Toei residents. We conducted 11 formal interviews with Khlong Toei residents, as well as created a Google Form with shorter, more specific questions, for which we received 44 responses. The interviews and surveys with Khlong Toei residents provided us with a better understanding of the residents' daily lives within the context of flooding. The interview included questions pertaining to the residents' work, commute, home life, and what they do, if anything, to mitigate the flooding and / or damage caused by flooding. We also asked questions to learn about what the residents believe to be the cause of flooding. A copy of our resident interview questions can be found in Appendix B, and the questions to our google form found in Appendix C.

We also interviewed representatives of the Port Authority of Thailand, a state corporation that owns the land of Khlong Toei. Because they own the land, they also have some responsibility for the well-being of the residents, and are therefore a stakeholder when it comes to flooding and the implementation of flood mitigating strategies. From our interviews we wanted to understand the relationship between them and the residents as well as gain insight as to what they have done to prevent flooding, or what they would not do and why. A copy of our interview questions with the Port Authority can be found in Appendix D.

Additionally, we interviewed Dr. Sopon Pornchokchai, a local researcher of slums, and Pavaris Meebangsai of the Thailand Department of Drainage and Sewage in order to gain third-party perspectives on Khlong Toei's flooding issues from people who do not represent any of the major stakeholders. We also intended to investigate the relationship between the stakeholders from an outside, unbiased perspective. A copy of our interview questions for Dr. Sopon Pornchokchai can be found in Appendix E.

Finally, we interviewed Pavaris Meebangsai, of the Department of Drainage and Sewage, to learn about regional rainfall and Bangkok's drainage system. From him, we intended to learn about rainfall patterns, the drainage in and around Khlong Toei, and plans for changes in the drainage system that pertain to Khlong Toei. Notes from our interview with Pavaris Meebangsai can be found in Appendix F.

3.3 Objective 3: Develop visualization tools displaying both notable contributors to flooding and areas most vulnerable to flooding.

The Duang Prateep Foundation and more specifically, Kru Prateep, has expressed interest in the creation of maps of Khlong Toei depicting elevation and any other pertinent contributing

factors to flooding. These maps make it easier for the Duang Prateep Foundation to portray the urgency of the flooding situation to local governments.

In order to accomplish this objective, we determined which measurements and data are the most significant not only for the Duang Prateep Foundation but also for developing flood mitigation techniques. To do this we used a geographic information software (GIS) program called QGIS to portray all of the data we had collected from Objectives 1 and 2.We used the software to map measurements we made as well as areas of the slum the residents reported to be the most vulnerable to flooding. This information was compiled onto an Excel worksheet and imported to the QGIS software. Using the longitude and latitude to determine the locations of the points, we were able to overlay different pieces of information on top of each other. This assisted us when analyzing our data, as we could then begin to analyze trends and patterns between pieces of data and attributes. Most importantly, we analyzed the trends that linked the areas that residents claimed to flood most severely to key infrastructural attributes. We chose which factors to portray based on the trends we were able to analyze as well as those which residents claimed to be the most significant.

After we had decided which factors we wanted to depict, we used QGIS to create finalized maps. Different data sets would require different types of maps, such as interpolated maps (gradient), points on a google satellite image, or data sets with transparency to clearly show correlations with the color scheme. Knowing that the Duang Prateep Foundation will be using these maps, we provided a brief explanation of each map and its relevance to flooding. The maps we created with the most notable contributors and other attributes may be found in our deliverable, Appendix H.

3.4 Objective 4: Identify feasible solutions to be implemented by the Duang Prateep Foundation in conjunction with the Port Authority of Thailand and the Khlong Toei District Office for long term flooding mitigation in the Khlong Toei slum.

We wanted not only to provide to the DPF the tools to illustrate residents' need for assistance from authorities, but also to provide to them an action plan of our recommendations. This would give the Duang Prateep Foundation a plan they could work to carry out with the relevant stakeholders.

In order to gain understanding of past efforts, we asked the residents, Duang Prateep Foundation officials, and community leaders about past efforts for flood mitigation. We were able to ascertain the efforts that had been tried by all those involved, which efforts in the past had worked, which efforts had failed, and why those unsuccessful efforts failed.

During our interview with Sopon Pornchokchai, we asked about past attempts to mitigate flooding in both Khlong Toei as well as other slums. We were also able to gain information about how the relationship between all of the stakeholders involved has caused a sequence of flood prevention strategies to fail, or not be put into action. We inquired to find what flooding mitigation strategies would be likely to be effective and sustainable for the people of Khlong Toei, as well as what had been done in other similar slum communities that we could replicate.

Conducting these interviews allowed us to create a framework for understanding the greater context surrounding flooding mitigation strategies in Khlong Toei. With this understanding, we were able to better determine what strategies would be effective and also something the people of Khlong Toei would be able and willing to continue. Acknowledging the timeframe before the monsoon season this year, we created a timeline for the DPF to put into action and use to motivate the

residents. This timeline provides them with feasible solutions, a timeframe for when these tasks should be done, as well as an indication of which stakeholders are responsible for each task. Using the maps we created as guides, we also created a plan for the locations of certain services to be provided. We intend for the Duang Prateep Foundation to meet with the Port Authority as well as the Khlong Toei District Office to enact this plan, as well as hold regular meetings to track the progress of these flood mitigation strategies.

Chapter 4: Findings

After analyzing the data we collected through direct observations and interviews during site visits in Khlong Toei, we determined the three following topics to categorize our findings: the current infrastructure and state of flooding in Khlong Toei, the major contributors to flooding and drainage problems, and the relationships between key stakeholders. The following chapter will further discuss our findings in relation to these themes.

4.1 Current State of the Drainage System in Khlong Toei

70 Rai is a planned section of the slum of Khlong Toei, designed and built by the Port Authority of Thailand for the residents living in the slum. Because this specific settlement is planned, there is also a planned drainage system in place for this area. Lock 4-5-6, however, is an unplanned settlement in the slum of Khlong Toei. Because it is unplanned, the drainage system is much less organized, and a large portion of the area has no drainage system in place at all.

The intention of the drainage system in Khlong Toei is to follow the elevation of the land to allow the water to flow south, draining into the Chao Phraya River. Lock 4-5-6 is at a higher elevation than 70 Rai, and thus the drainage system is designed to allow the water to travel downhill, towards 70 Rai to the south, then through large drainage ditches in 70 Rai and out the bottom into a larger main canal. The canal then leads to pipes located underneath the Port Authority that dump the water out into the Chao Phraya River. A map of the elevation can be found in Appendix B.

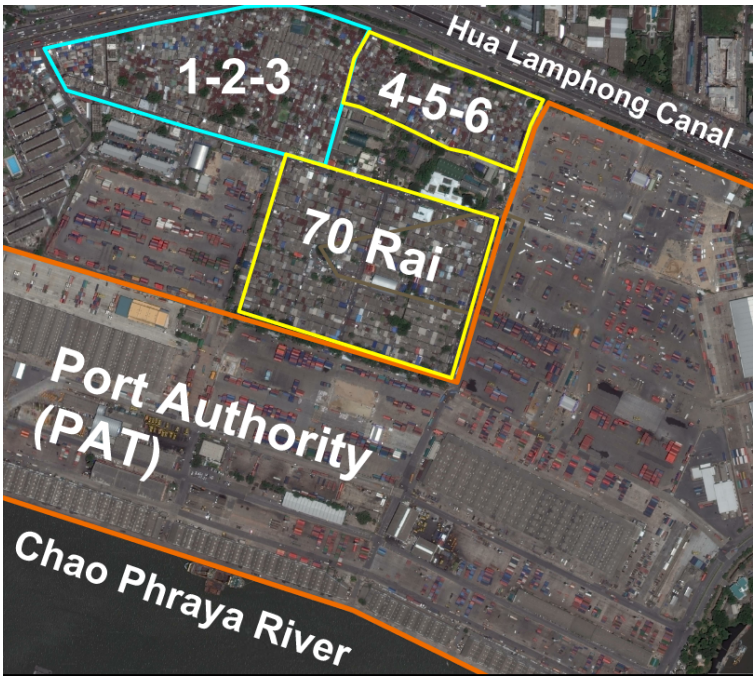

Figure 4.1: Aerial Road Map of Khlong Toei Provided by DPF

Finding 1: Failing drainage systems lead to flooding in Khlong Toei.

Our team found that there is a planned drainage system in 70 Rai and no formal drainage system in Lock 4-5-6. Though some informal drainage systems exist in Lock 4-5-6, we concluded

that these drainage systems – and even the planned drainage in 70 Rai – frequently do not work as intended and overflow, resulting in flooding. From our interviews and first-hand inspection, we found that water located in the drainage trenches – both planned and unplanned, situated along the sides of the walkways is primarily stagnant and is pooling due to clogging. Such clogging leads to overflow and flooding in times of intense or extended rainfall (Appendix H). Floodwaters then flow to the areas of lowest elevation. The low-lying locations are the areas that are most severely affected by flooding.

When we analyzed the drainage systems in these communities, the height of water in drainage trenches from common walkways was the first aspect we considered. Pictured in Appendix C, we noted that the standing water in the northern area of Lock 4-5-6 is much closer to the surface of such common walkways than it is in 70 Rai. Within the 70 Rai community, the southeastern quadrant displays similar characteristics. This high level of water in drainage trenches means only a minimal amount of water level rise is necessary to cause an overflow of the drains.

We also observed a general lack of flow in the drainage trenches throughout the majority of the Lock 4-5-6 and 70 Rai communities, as shown in Appendix F. This means that when rainfall pours into the drainage trenches, rather than initiating flow, the newly deposited water pools together with the standing water. The combination of stagnant water and already high water levels leads to rapid water level rise in events of rainfall, leading to flooding.

Our team also found that when water does flow, rather than flow southeast from Locks 4-5-6 to the Chao Phraya River, as originally designed by the Port Authority, it must be redirected to the Hua Lampong canal to the far northeast of the community. This is because the Port Authority of Thailand sealed the drainage pipe to the Chao Phraya with a cement wall five years ago (Kru Prateep, 1/5/2017). This action forced the Duang Prateep Foundation and members of the community to redirect water to flow through drainage pipes from the southeastern corner where it naturally gathers to the northeast of the settlements where the Hua Lampong canal is located.

The true reason behind the closing of the drainage system remains slightly unclear and most likely consists of a couple contributing factors. According to Kru Prateep, the Port Authority closed the drainage system in part because residents were sneaking through the pipes and stealing from the Port Authority. According to an interview with Dr. Sopon Pornchokchai, a researcher of slums in Bangkok, the sealing of the drain corresponded to concerns regarding the quality of water draining through the Port Authority's land and out into the Chao Phraya River. After speaking with Port Authority officers, we learned they did originally seal the pipes with a metal fence, allowing water to still flow, but the residents removed the fence in order to sell the material (Port Authority of Thailand, 2/9/2017). These actions by the residents occurred around 5 years ago and are what prompted the Port Authority to seal the drains with a cement wall. They wanted to protect access to their land and stop polluted water from flowing into the Chao Phraya River. This is highlighted in Appendix I, our interview with Port Authority officials.

Finding 2: The untreated wastewater does not meet the standard to release to Chao Phraya River.

We collected water from 70 Rai and submitted it to the Environmental Research Institute at Chulalongkorn University. Using the standard methods for examining water and wastewater, we tested for pH, settleable solids, total suspended solids (TSS), total dissolved solids (TDS), oil & grease, chemical oxygen demand (COD), biochemical oxygen demand (BOD), total Kjeldahl nitrogen (TKN) and sulfide. We compared the results (Appendix P) with the acceptable quality of water based on the Pollution Control Department of Thailand and found that TSS, COD, BOD and

sulfide results are higher than the standard value due to the organic matters from trash. As the water quality at the south of 70 Rai does not meet the Ministry of Natural Resources and Environment standard, it cannot be released into the Chao Phraya River due to the environmental impact. From an interview with Dr. Sopon Pornchokchai,

4.2 Major Contributors to Flooding and Drainage Problems

Through measurements and observations, we aimed to determine the major contributors to flooding in Khlong Toei. By overlaying all of our data into a Geographic Information System, the correlation between elevation, trash and sediment buildup, and flooding susceptibility became obvious. This section will clarify this correlation and explain the impact that elevation and the buildup of trash and sediment has on Khlong Toei's flooding and drainage problems.

Finding 3: Lower lying areas in Khlong Toei are more susceptible to flooding.

Using the Google Maps Elevation API, we were able to collect elevation data throughout Khlong Toei and add it to our Geographic Information System, creating a map of elevations that can be found in Appendix M, map 2. The lowest lying areas of the slum are the western majority of Lock 4 and the south of 70 Rai. As water naturally flows to lower elevations, we determined that the lower lying areas of Khlong Toei would be especially susceptible to floods. Confirming our beliefs, our interviews with the residents of Khlong Toei clearly indicated that the western majority of Lock 4 and the south (especially the southeast) of 70 Rai were more flood-prone than the rest of the slum. A map depicting the areas that the residents reported to be the most susceptible to flooding can be found in Appendix M, map 1. While elevation is a contributor to the susceptibility to flooding in these areas, it was not the only factor that we found.

Finding 4: The buildup of trash and sediment exacerbates vulnerability to flooding.

While making our measurements and observations in Khlong Toei, we noted a strong correlation between areas with prominent trash buildup (Appendix M, map 7) and the areas that the residents stated to be most flood-prone. Furthermore, 67% of the interviewed residents believed trash to be a major contributor to flooding in Khlong Toei and 51% believed that the drains being clogged by sediment and/or trash are a key factor.

We also saw a correlation between trash buildup and the location of trash bins in 70 Rai, mapped in Appendix M, map 9. Our interviews with residents indicated that if a trash bin is full, some residents will throw their trash beside the bin. When the District comes to collect trash in the bins, waste left beside the bins does not get collected and can find its way into nearby, open drains where there is little chance for it to get picked up. Only 25% of the residents we interviewed clean trash from the drains in front of their homes themselves and 5% hire someone else to do it. Further, 45% of those interviewed admitted to doing nothing at all. A significant portion of the trash that is not picked up gets caught in the drains and flows with the water to areas of low elevation where it clogs drains and causes them to overflow, exacerbating flooding.

Like trash, a large amount of sediment follows the flow of water to the low-lying areas of Khlong Toei. Where we measured sediment, we found that it occupied an average of 32% of the depth of the drains. Sediment reduces the effective depth of the drains, making them more likely to overflow and begin to flood the surrounding area.

From these findings, the reader can see that areas that are most vulnerable to flooding are those where the water naturally flows, bringing with it trash and sediment which only exacerbates

flooding. Especially in the case of 70 Rai, the flow of water is largely dictated by the necessity to pump the water up towards the Hua Lampong Canal instead of allowing it to flow down to the Chao Phraya River, through the pipe that was blocked off by the Port Authority of Thailand. This makes the southeastern corner of 70 Rai the most vulnerable to flooding.

4.3 Stakeholder Relationships

One of the fundamental reasons little has been done to address flooding in Khlong Toei is the tendency of key stakeholders to push responsibility off on each other. In order to examine the relationships between these entities, we interviewed the Duang Prateep Foundation, the Port Authority of Thailand, as well as the President of the Thai Appraisal Foundation and researcher of Bangkok's more than one thousand slums, Dr. Sopon Pornchokchai.

Finding 5: Many residents of Khlong Toei lack motivation to improve their quality of living.

Many residents of Khlong Toei believe that since the Port Authority of Thailand owns the land on which they live, the Port Authority should help them. Echoing many of the squatters in Khlong Toei, one influential resident stated, "the Port Authority should help because they are the landlord" (Resident, Soi 30). About 25 years ago, the Port Authority granted a 30-year lease to the residents when their previous lease was ending and talk of eviction began to arise. This allowance, along with the large amount of time the residents have inhabited this land has led to the residents believing the Port Authority to be a sort of landlord who should assume the responsibility of maintaining the land the residents are living on (Kru Prateep, 1/5/2017).

With 70 Rai's 30-year lease now coming to an end, many residents live with the expectation that they could be evicted at any time. This expectation creates is a general lack of commitment to their current home. Many residents have little motivation to improve their quality of living and do not take responsibility for their property. Basic tasks such as clearing the drains in front of their own home are neglected. This attitude makes it difficult to implement long-lasting, effective programs into the community.

Community waste management programs in the past have shown promise, but have died out due to a lack of funding, volunteers, or commitment from the residents of Khlong Toei. With many residents believing they could leave at a moment's notice, it is understandable how they might not have faith or interest in a structured community program, even if it is designed to improve their current home.

One of the most successful attempts at improving the waste management problem was a program called "Garbage for Eggs" which was started in 1997 by the Environmental Organization Group of Thailand. Residents of Khlong Toei would bring their trash from the week to a stand and exchange it for eggs (Jameison, 2000). This program saw a great deal of success over the course of eight months, saving nearly 2,000 metric tons of waste (Jameison, 2000), because it provided the residents a tangible, short-term incentive for cleaning up the slum (Resident, Soi 30, 1/19/17). Over time, however, the program could not sustain itself due to an insufficient amount of volunteers, commitment from residents, and funding for proper equipment (Resident, Soi 30, 1/19/17)). Another more informal effort to manage the waste buildup in Khlong Toei was started by one of the community leaders in the past named Wanlop. He placed extra trash barrels around the entire community and organized people every weekend to help move out the trash and clear the clogged pipes. Similarly, this program died off over time due to inconsistent commitment from the residents (Resident, Soi 1, 1/19/17).

Finding 7: The Khlong Toei District Government has only recently signed on to help clean the drainage in Khlong Toei.

One of our most significant findings was the reported major disconnect between the way the Bangkok government (specifically the Khlong Toei District Office) and the Duang Prateep Foundation, view the residents of Khlong Toei. The District Office believes "the residents do not want to clean the pipes because in the past they have gone to the Khlong Toei slum to try and help clean the pipes but only a few of the residents helped" (Natsurang Pongchakran, General Staff of Drainage in Khlong Toei District, 1/31/2017). However, this could be explained by the fact that most of the residents are working whenever the District offers to help (Non, 2/6/2017). Consequently, the government takes a backseat role in helping those in poverty because they believe that if people truly wanted help, they would at least begin to help themselves. The government seems to want to see a self-started effort showing promise before they devote resources to assisting the poor. In contrast, the Duang Prateep Foundation, and members of the lower socioeconomic classes in Thailand, view the poor as the foundation of business in Thailand, providing a cheap workforce to business (Kru Prateep, 1/5/2017). Consequently, the poor do not see themselves as lazy; they regard themselves as having earned the right to the services of the government.

However, the Khlong Toei District recently visited the Khlong Toei slum on February 13, 2017 to help the residents clean the drainage system. This day was a national Buddhist holiday so many of the residents were home and able to help. The District cleaned the main pipe which runs down the middle of Lock 4-5-6 and 70 Rai and supplied bags for residents to clean the smaller trenches in front of their homes (Non, 2/15/2017). Apparently one of the reasons this help had not come earlier was because the leader of Lock 4-5 had not filled out the proper paperwork which the District requires (Non, 2/15/2017).

Finding 7: The goal of the Port Authority of Thailand is to evict current residents for business expansion on the land of Khlong Toei.

Through interviews with both the Port Authority of Thailand, the Duang Prateep Foundation, and Dr. Pornchokchai, we determined the goal of the Port Authority is to eventually evict the residents, or slowly pressure them to leave on their own, so that the Port Authority can use the land to expand their business. Deachar Nuchpoom, the Director of the Asset Management Division of the Port Authority of Thailand, says "The port wants to drive out the residents to create more space for storage for the Port Authority" (Deachar Nuchpoom, 2/9/2017). Dr. Pornchokchai suggested commercial development could be an alternative motive as land on the Chao Phraya is highly valued. Additionally, representatives from the Duang Prateep Foundation say they believe the port does not care about the residents in the slum. The port just wants to reclaim the area that the residents live on because of its prime location within Bangkok. (Kru Prateep, 1/5/2017).

From the interview with the Port Authority of Thailand, we learned the port has collaborated with the Khlong Toei District Government to design a plan to clean the drainage system in Khlong Toei. The Port Authority is working with an organization called the Mercy Center to provide funding of one hundred thousand baht to start a program that will pay residents 1 baht per kilogram of wet trash that they remove from the drainage system. This program is still in a stage of planning, but would be another possible way to motivate the people of Khlong Toei to clean their drainage system (Deachar Nuchpoom, Director Asset management Division, Port Authority of Thailand, 2/9/2017).

While this plan may seem like a sign that the Port Authority wants to help the residents combat their flooding problem, its true purpose, from the perspective of the Port Authority, is just

to maintain the quality of the pipes and drainage system of the land that they hope to eventually reclaim (Deachar Nuchpoom, Director Asset management Division, Port Authority of Thailand, 2/9/2017).

4.4 Limitations

As with any project of this kind, where we are limited in time and resources, we have run into areas where we could not fully investigate every detail and aspect of the slum that pertains to flooding. Because of this, we have provided this section with our shortcomings and areas that would require further investigation to fully understand the aspects of the slum.

The most significant limitation was not being able to examine flooding first hand. This project revolves around the rainfall during the monsoon season, July through October, while the timeframe of our project was January through February. Because of this, we were not able to experience first hand the effects of flooding, and required us to rely heavily on our interviews to understand these issues. We recommend performing similar data collection and studies while the flooding is occurring. Being able to track the data we collect while the flooding is occurring would be very valuable to the validity, accuracy and relevance of these studies.

Another shortcoming we came across was with the data collection. We wanted to use different elevation techniques than the Google API for the sake of accuracy, but because of our time and budget, we were unable to find the resources to do this. We recommend, for further accuracy of elevation within the slum, that better technology for measuring elevation, such as a GPS or physical elevation tracker, should be used.

We ran into a problem when trying to analyze the rainfall data, and trying to make any correlations with that. We found the data to be useful for measuring flooding, however there are too many factors to keep track of, making it too complicated to make any sense of. We would need to know the rate at which water is able to flow out of Khlong Toei, as well as how much water comes in from other areas.

We came across a problem where we did not have as many responses and interviews with residents as we desired. Because most people we were hoping to talk to were working during the day when we were able to visit Khlong Toei, we made a Google form for them to fill out on their phones. We realize now that we should have done this sooner so that we could analyze our data more completely.

QGIS is a great software for our purpose. However, we had very little time to learn it. We were able to use the software successfully, but we did not have enough time to explore the software fully. A greater understanding and experience with the software could lead to more detailed and accurate maps.

Chapter 5: Recommendations

Our recommendations and conclusions are influenced by the findings and information discussed in the background chapter. We organized them by anticipated effectiveness and feasibility.

1. We recommend community leaders organize a community effort to clear obstructions in the drainage system.

Drainage is crucial to preventing flooding during periods of intense rainfall. As we uncovered in Finding 1, the drainage paths in Locks 4-5-6 and 70 Rai are obstructed and preventing water flow and in some places drainage trenches are entirely absent. Therefore, we recommend removing blockages including cement covers, trees, vegetation that has arisen, and anything else that is preventing water flow, as well as digging new sidewalk drainage trenches. Last year a member of the board of community leaders, Bermt, led an effort to break up cement-filled drainage ways in the southern portion of Lock 5. His work not only resulted in increased water flow but also significantly decreased flooding in that specific area. Our team recommends conducting similar efforts – essentially community cleanup days – in the greater communities of Locks 4-5-6 and 70 Rai on a recurring basis. Community leaders will lead this effort within the slum in partnership with the Duang Prateep Foundation. From inspection of the slum, we found the eastern portion of Lock 4 and southeastern portion of 70 Rai to be the most glaringly affected by trash buildup – we recommend those areas be given priority in cleaning efforts. The community leaders should then enlist the financial help of residents who are able to contribute to the securing of proper tools for the project. Additionally, these community leaders will have to recruit support of property owners where clogging is present to ensure their cooperation. The feasibility of this recommendation is quite high due to relatively low cost and time commitment.

2. We recommend residents add new drainage outflow pipes to the slum.

The Khlong Toei drainage system has little connection to canals or to the Bangkok Metropolitan drainage system. Last year the residents installed a new pipe in the northern part of Locks 1-2-3 underneath the railroad, which led water directly to the Hua Lamphong Canal, instead of passing the water down through 70 Rai. We recommend the residents of Locks 4-5-6 add similar drainage infrastructure that would connect the informal drainage in the slum to the larger drainage resources. A map has been attached outlining location of this outflow pipe in Appendix O, maps 2 and 3. This additional drainage would allow for more possible routes of water flow towards the main drain, leading to greater floodwater management. The cost implicated with the pipe installed last year was close to 150,000 THB. This financial burden taken on by the Duang Prateep Foundation was 10,000 THB while the Mercy Foundation, another non-profit in Khlong Toei, and the Port Authority took responsibility for the rest of the cost. This recommendation would be highly effective as it almost entirely mitigated flooding in Locks 1-2-3; however, the feasibility is low because the cost is high.

3. We recommend that the Duang Prateep Foundation and community leaders establish waste management initiatives with the residents.

Finding 3 indicated that locations with high trash buildup are more susceptible to flooding and that while residents will use the District provided trash bins, trash that overflows from them or gets placed near them often finds its way into the drainage system. A waste management initiative would reduce the likelihood of residents polluting Khlong Toei. There are initiatives that require significant resident involvement, and others that primarily rely on outside sources for help. Internally, the DPF could lead the formation and advertisement of programs similar to those that have been tried in the past. These are "Garbage for Eggs," a waste exchange program put forth by the Port Authority or "Trash for Toothpaste," an effort by the Mercy Foundation to try to eliminate the issue of pollution in Khlong Toei drainage systems. In both initiatives, residents would turn in trash they had – either retrieved from drains or waste they had created themselves – and receive some sort of reward. Currently, as was found in interviews, the Port Authority is planning some time in the near future to implement a waste exchange program for the slum similar to what they tried in the past; the DPF could look into collaborating with the Port Authority to see the successful implementation of this project. Initiatives like this which involve residents are more likely to have an impact than initiatives which do not because residents are more likely to advocate for maintaining the cleanliness of something they have cleaned personally – the drains. We also learned of an individual in Lock 5 who collects a small weekly sum from residents and will collect trash from their homes. The Duang Prateep Foundation could look further into expanding that business model, creating jobs and cleaning the community at the same time. Externally, the Duang Prateep Foundation and community leaders could consider expanding the waste collection service provided by the Khlong Toei District Office. There are many options for waste management that the DPF can look into.

Additionally, we suggest that any waste management initiative should add emphasis to clearing sediment from the drains, as we have found that to be an important but often overlooked factor of flooding vulnerability. We believe that implementing this recommendation is very possible and would improve the state of flooding vulnerability in Khlong Toei in the long term.

4. We recommend the DPF record flooding events whenever they occur.

We recommend creating a running record of flooding in the slum. This information will be recorded and kept by community leaders working with the Duang Prateep Foundation. In the instance of flooding, such community leaders will note areas affected, duration of rainfall event which caused flooding, duration of flooding, height of standing water, and general notes regarding any special characteristics of that flooding event that may be unique. This information will be kept and stored as a resource for future projects that may address the issue of flooding in Khlong Toei, enabling them to analyze trends between days of significant flooding.

5. We recommend that the Khlong Toei District add more trash bins in Locks 4-5.

We recommend members of the DPF and community leaders within the slum petition the Khlong Toei District Authority for more trash bins, an expansion of the trash collection service that is present now. They should be placed at locations in Locks 4 and 5 both where there is significant trash buildup and little waste management and where the District will be able to service the bins. The proposed locations have been outlined in Appendix O, map 1. The trash bins will be ineffective

without proper waste management programs. Community leaders should ensure those areas of the community that will be serviced will also be willing to pay for the trash collection service from the District Office.

6. We recommend installing fences surrounding communal waste dumps to contain waste in the event of flooding.

From our research and interviews, we learned that trash buildup in drains is a major contributor to standing water and lack of flow. There are several open trash dumps and large accumulations of trash in Locks 4 and 5, with the largest at the southern entrance to Locks 4 and 5. Major trash buildup has been outlined in Appendix M, map 7. We recommend that such communal trash dumps and buildups have fences built around them. The community leaders within each area should lead this effort. Temporary fencing such as plastic mesh fencing attached to steel posts would be adequate to accomplish the desired function. Necessary amounts of these materials for a ten-meter square area can be found at HomePro for approximately 750 THB. We recommend the fence be approximately 1 - 2 meters in height in order to ensure trash containment even during times of heavy rain. One of the concerns of this approach is the security. In the past, residents have stolen pieces of fencing in order to sell the materials. Despite this concern, this recommendation is extremely feasible due to the low cost of temporary fencing solutions.

7. We recommend that the DPF establish a recurring cleanup day of existing drainage outflow infrastructure.

We recommend the Duang Prateep Foundation work with community leaders within the local communities and members of the Khlong Toei District Office to establish regular cleanings of major drainage outflow pipes. As was discovered in Finding 7, the Khlong Toei District does work to clean drainage outflow pipes in the slum, provided the proper paperwork for request of cleaning has been completed. We recommend the Duang Prateep Foundation help community leaders to complete their respective paperwork and establish a schedule of dates when the responsible parties would be available and the District Office would be willing to clean these drains. We recommend this action be taken at least annually, if not quarterly, to maintain proper outflow to major drainage infrastructure. We recommend this action be taken in each lock of the slum.

8. We recommend the Khlong Toei District work with the DPF to build a water treatment station.

Due to the absence of septic tanks and similar water treatment infrastructure, wastewater from homes in Khlong Toei drains directly from bathrooms and kitchens into community drainage. As a result, the water that collects in Khlong Toei's drainage canals, especially the canal at the southernmost portion of 70 Rai, is full of untreated sewage, waste, sediment, and chemicals. One of the key reasons the Port Authority refuses to open the drainage at the southeast corner of 70 Rai is because the water is well below required standards for discharge into the Chao Phraya River. They do not want to be held responsible for this hazardous, contaminated water flowing through their land and into the Chao Phraya River. We suggest the Khlong Toei District and the DPF work together to investigate building a water treatment station capable of improving the water quality to acceptable standards in hopes of persuading the Port Authority to reopen the drain. The feasibility

of this recommendation depends on the level of technology utilized for the water treatment station, as well as installation and maintenance costs. We recommend the DPF work with the District Office on behalf of the residents to procure funding and assistance to create this water sanitation station. Some low cost options have been researched and are included in Appendix P. Overall, this solution would be extremely effective because it directly targets the main concern of the Port Authority regarding sealing the drain to Khlong Toei.

9. We recommend the DPF organize regular meetings with all relevant stakeholders to go over the progress of the agenda we supply to the DPF.

Our final recommendation is meant to help improve the relationships between key stakeholders in the community of Khlong Toei. We recommend the DPF schedule and conduct meetings with stakeholders at regular intervals. The key stakeholders are the DPF, the community leaders of the slum, the Khlong Toei District Government, and the Khlong Toei Housing Cooperative, which is a non-profit organization working for the Port Authority as an intermediate landlord between the PAT and the residents. At these meetings, we recommend the DPF remain transparent regarding successes they and residents have, illustrating to stakeholders that they are taking initiative to manage their own problems as a gesture that will encourage other parties to become more involved. Bringing the relevant parties to the table, in-person, will give them the chance to voice concerns, intentions, and share progress and direction. Keeping everyone on the same page allows the DPF to most effectively achieve the goal of flooding mitigation in the Khlong Toei slum. Meetings between these parties have taken place in the past and have led to progress and direction, and we anticipate similar results.

Chapter 6: Conclusion

Our project examined the major contributors to flooding in our focus area of Locks 4-5-6 and 70 Rai in the Khlong Toei slum in Bangkok, Thailand. We found that flooding occurs in both locations, regardless of the presence of a planned drainage system in 70 Rai. Flooding in Khlong Toei is primarily caused by ineffective waste management practices. Open dumping of waste leads to clogged drainage systems, which flood during period of intense rainfall. Additionally, water is being forced to flow down into the southeast corner of 70 Rai and back towards the Hua Lampong Canal, contrary to the initial design that planned for the water to drain directly into the Chao Phraya River. This inefficient drainage pattern creates more opportunities for flooding. We learned one of the most promising approaches to this problem would be to recommend water quality and waste management solutions to the DPF to help them persuade the PAT to reopen this direct drain into the Chao Phraya River. Our recommendations are designed to target waste management in the slum and improve the water quality as a result.

When examining the social context surrounding flooding, we noticed the residents of Khlong Toei lack motivation to act on the problem because they are currently nearing the end of a 30-year lease for the land. This attitude makes it very difficult for community waste management initiatives to gain traction. The project deliverable provides the Duang Prateep Foundation with tools such as maps depicting flooding vulnerability, recommendations which can serve as references for bringing about governmental action, and a guide for planning improvements to the drainage systems in the community. We believe that the creation of this deliverable will enable the DPF to encourage government leaders to take action, and will empower them to lead community members to take action themselves.

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Appendix A: Interview Questions for Duang Prateep Foundation and Kru Prateep

Preamble:
[Interview with our sponsor – no introduction necessary]
Your participation in this interview is completely voluntary and you may withdraw at any time. If you would like, we would be happy to include your comments as anonymous, though it would useful for readers to know who your name and/or position at the Duang Prateep Foundation. We can email you any quotes or information we use from our interview with you for you to approve before we release our results.

Goals/expectations from this interview:
Understand the direction/end goal the DPF has for Khlong Toei in terms of flooding management/mitigation: past efforts and future plans and how this project fits in the accomplishment of those goals.

1. What does the Duang Prateep Foundation see as its end goal in terms of flooding?
    a. Where does the Duang Prateep Foundation currently stand in terms of reaching this goal?
2. What are the Foundation's best/most successful efforts in terms of flooding? Why was it successful?
3. What have been the biggest obstacles you have had to deal with in previous attempts to mitigate flooding?
4. Where do you see an opportunity for the Duang Prateep Foundation to better achieve their goals in terms of flooding management?
    a. What stands in the way of achieving this improvement?
5. Can you speak towards the government involvement in flooding mitigation efforts/cooperation with the Duang Prateep Foundation?
6. What can the government change on a policy level in the context of flooding that would be able to better the lives of the slum residents?
7. Are you aware of any plans the government has with the area of Khlong Toei?
8. What information from last year's IQP-ISSP did you find useful to help the efforts towards the Duang Prateep Foundation's flooding goal?
9. What tools would you find useful to possibly make a case to government officials to enact action on a policy level?
10. What is the general attitude of reception you see in the residents?
11. How have specific efforts on flooding mitigation in the past been perceived by residents?

Appendix B: Interview Questions for Khlong Toei Residents

Preamble:
We are a group of students working with the Duang Prateep Foundation conducting interviews with residents of Klong Toei to learn more about their experiences with flooding. Our goal is to offer the Duang Prateep Foundation a visualization of vulnerability due to flooding within Klong Toei and your insights will be extremely useful.
Your participation in this interview is completely voluntary and you may withdraw at any time. If you would like, we would be happy to include your comments as anonymous.

Goals / expectations from this interview:
To have more data and new ideas about this project. Learn about the residents' viewpoints and their feelings towards flooding within Khlong Toei.

1. General Life in Khlong Toei Questions
    a. What do you like about living here?
    b. What would you like to see improved about Khlong Toei?
        i. How do you think those changes could be implemented?

2. Flooding Questions
    a. Are you affected by flooding in this area?
    b. In what way does flooding impact this area?
    c. In what ways are you, personally, impacted by flooding?
        i. What do you do during the flood? Do you need to make any repairs after floods?
        ii. How is your daily life impacted by flooding?
        iii. Is your daily commute / transportation affected by flooding?
            1. In what way?
            2. Is it more dangerous?
            3. How does this affect your work?
    d. What do you think is the biggest reason for the flooding?
    e. Has flooding gotten any better or worse over time?
        i. Was it a gradual change or was there a specific event that made flooding better / worse?
    f. What do you do personally to manage flooding?
    g. Have you seen efforts to mitigate this flooding from other organizations?
        i. What / who have you seen?
        ii. Was this approach successful (if there was an effort)?
        iii. In what ways did this approach fail (if there was an effort)?
    h. If you could suggest one solution to flooding, what would you suggest?

3. Waste Management Questions
    a. How do you dispose of your trash?
    b. How do you remove large/small trash items?
    c. How often do you remove trash?
    d. Where do you remove your trash to?

e. Why do you think people openly dump waste in the community?
f. Has trash buildup in the canals caused any change in the water?
    i. In what way?
    ii. Is it the large waste or small waste?
g. Are there trash cleaning services or other kinds of waste management?

4. Duang Prateep Foundation Questions
    a. Has the Duang Prateep Foundation affected you?
        i. How have they affected you? What services have they provided?
        ii. The Duang Prateep Foundation would like to help Khlong Toei with the flooding, what do you think they would be able to do? What would you like them to do?
        iii. Do you think the Duang Prateep Foundation needs to help you? Why? Why not?

5. Port Authority Involvement Questions
    a. Has the Port Authority or other government branch done anything in the past to influence the flooding for better or for worse?
        i. What have they done? Do you like it? Why? Why not?
    b. What would you like to see them do to help mitigate flooding?
    c. Has the Port Authority made any construction that has affected you, or would have affected the flooding?
    d. What do you understand the role of the Port Authority of Thailand to be?
    e. Do you think the government should help you? Why or why not?

Appendix C: List of Questions on the Google Form for Khlong Toei Residents

1. Name/address/career?
2. Are you affected by the flooding problem?
    a. How often?
    b. How is it?
3. When does it start to flood?
4. What do you think are the causes of flooding?
5. How do you manage your trash?
6. Have you seen any outside parties (DPF, PAT, the District, etc.) help?
7. How do you solve the flooding problem by yourself?
8. What do you think about campaigns like "Garbage for Eggs?"
    a. Are they helpful?
9. What do you want to recommend about this problem?

Appendix D: Interview Questions for the Port Authority of Thailand

Preamble:

We are a group of students working with the Duang Prateep Foundation on a project in the Klong Toei Slum. Our goal is to offer the Duang Prateep Foundation a visualization of vulnerability due to flooding within Klong Toei and your insights will be extremely useful.

Your participation in this interview is completely voluntary and you may withdraw at any time. If you would like, we would be happy to include your comments as anonymous, though it would useful for readers to know who your name and/or position at the Port Authority of Thailand. We can email you any quotes or information we use from our interview with you for you to approve before we release our results.

1. What is your position in the Port Authority of Thailand?
2. What do you enjoy most about your position?
    a. Why is that so important to you?
3. In times of flooding, does the government have any plan of action to help the people of the slum?
    a. What were the outcomes?
4. What does the Port Authority of Thailand do for managing or clearing floodwater?
5. Are there waste management services provided to Khlong Toei, specifically the slums in Locks 4, 5, 6 and 70 Rai?
6. Are there trash areas or bins provided to the residents of Khlong Toei?
    a. Who provides these services?
7. Are there developmental plans for Khlong Toei?
    a. Would you be willing to share those plans?
8. We are aware that the Port Authority of Thailand closed the pipes that dispensed the water from the slum into the Chao Phraya River. Would you be willing to go into more detail as to why this decision was made?
    a. Could you go into more detail in the decision to block the pipes with cement rather than something porous such as bars?
9. Last year, there was a meeting held to discuss the issue of flooding in Khlong Toei. We would be interested in hearing from your perspective the progression and outcomes of this meeting. Were you personally involved?
    a. If yes, would you be willing to give us more information as to what happened?
    b. If not, would you still be able to inform us as to what happened?
    c. If not, would you be able to put us in contact with someone who was there or could share more information about this meeting?
10. To make the Port authority to open the drainage system, do you know how to make it and whom we have to talk with?
11. Talking about the agreement that have made, how many years? When does it start? When it is going to finish?

Appendix E: Interview Questions for Dr. Sopon Pornchokchai

This was an informal interview. These Questions were utilized as leading questions to guide the conversation; many of them were answered indirectly in the natural direction of the conversation.

Preamble:

We are a group of students working with the Duang Prateep Foundation on a project within the Klong Toei Slum. Our goal is to offer the Duang Prateep Foundation a visualization of vulnerability due to flooding within Klong Toei and your insights will be extremely useful.

Your participation in this interview is completely voluntary and you may withdraw at any time. If you would like, we would be happy to include your comments as anonymous, though it would useful for readers to know who your name and/or occupation. We can email you any quotes or information we use from our interview with you for you to approve before we release our results.

Goals/Outcomes of the interview:

To understand slums and give us insight to vulnerability to flooding as well as future developments and tendencies in the slum. This is also an opportunity to us to give us a more specific direction with our project, what will actually be needed for DPF to enact policy change.

1. Could you talk a little about the formation of Khlong Toei and why flooding is such an issue in the area now? (*If not Khlong Toei specific,* Could you talk about the formation of slums in general in regards to why flooding would be an issue?)
    a. Is there anything in the recent history of the slum that has made conditions worse? (*If not Khlong Toei Specific,* What changes in the modern development of slums make conditions worse for flooding?)
    b. Do you foresee conditions worsening?
        i. If yes, what would lead to this?
        ii. What could be done to prevent this?
2. What specifically could the government do?
3. Could you speculate what the most significant issue associated with flooding in slums could be?
4. Can any projections be made as to the worsening of flooding in the slum of Khlong Toei?
    a. Is there a way we could research this topic – maybe first hand in the slum, in order to gather information and make projections for how it might worsen?
    b. Can you speak about the reasons the PAT closed this drainage way?
    c. Do you think there is any chance they might reopen it?
    d. The main outcome the DPF wants to see is the reopening of this drain – are there more realistic options for flooding management in Khlong Toei?
5. Taking into account successful efforts in the past, what steps should the Duang Prateep Foundation take?
    a. The Duang Prateep Foundation has asked us to make a map that shows water flow and vulnerability to flooding in the slum, in addition to this what do you think would be a useful tool that we could provide the DPF in order to help them do this?
6. What are typical social problems that arise when trying to create policy change in the slum / in slums in general?

7. What is the estimate land price for the Khlong Toei slum?

Appendix F: Interview Questions for Pavaris Meebangsai

Interview with official from Thailand Department of Drainage and Sewage Pavaris Meebangsai

Preamble:

We are a group of students working with the Duang Prateep Foundation on a project in the Klong Toei Slum. Our goal is to offer the Duang Prateep Foundation a visualization of vulnerability due to flooding within Klong Toei and your insights will be extremely useful.

Your participation in this interview is completely voluntary and you may withdraw at any time. If you would like, we would be happy to include your comments as anonymous, though it would useful for readers to know who your name and/or position at the Thailand Department of Drainage and Sewage. We can email you any quotes or information we use from our interview with you for you to approve before we release our results.

1. What is the volume of the rainfall per year in Bangkok?
2. What is the trends for rainfall?
3. What is the process of drainage system?
4. How does the rainfall cause flooding?
5. Where is the pump station around Khlong Toei?
6. How many pump take care around Khlong Toei area?
7. How long does it take to pump the water out from the canal?
8. How they handle during the flooding?
9. How do you manage the wastewater?
10. How do you know when it is going to rain? When do you start operating the pump?
11. How do you calculate the amount of water released to canal or to the river?

Appendix G: Results from Google Forms for Residents

Of 44 interviewed, more than half had no response when asked for suggestions to solve flooding

- 77.3 percent of residents homes flood, 22.7 do not

How many times per year?

- 48.7 more than six times per year
- 25.6 more than once per year
- 12.8 more than three per year
- 7.7 more than 2 per year
- 5.1 more than 5 per year

When does it start to flood?

- 51.3 percent said 30min to 2 hours after start of rain
- 43.6 percent said after 2 hours
- 5.1 percent said even without rain

Effect from flood:

- 59.5 say they can still commute, but harder
- 56.8 said they experience danger from animals
- 21.6 damages furniture
- 10.8 percent trapped in house
- 10.8 experience disease

What is the cause?

- 67.4 because of trash
- 51.2 because of clogged drain
- 20.9 because of low land
- 16.3 because of bad drainage system
- 7 percent other
- 2.3 percent global warming

How do you dispose of your waste?

- 59.1 use trash can in front of house
- 22.7 use trash can somewhere other than in front of house
- 9.1 someone collects their trash
- 6.8 openly dump
- 2.3 not sure, just anywhere I want

Received help from external organization

- 60.5 said no organizations ever help
- 22.3 yes from Khlong Toei district
- 16.3 yes from other

How did you cope with this problem?

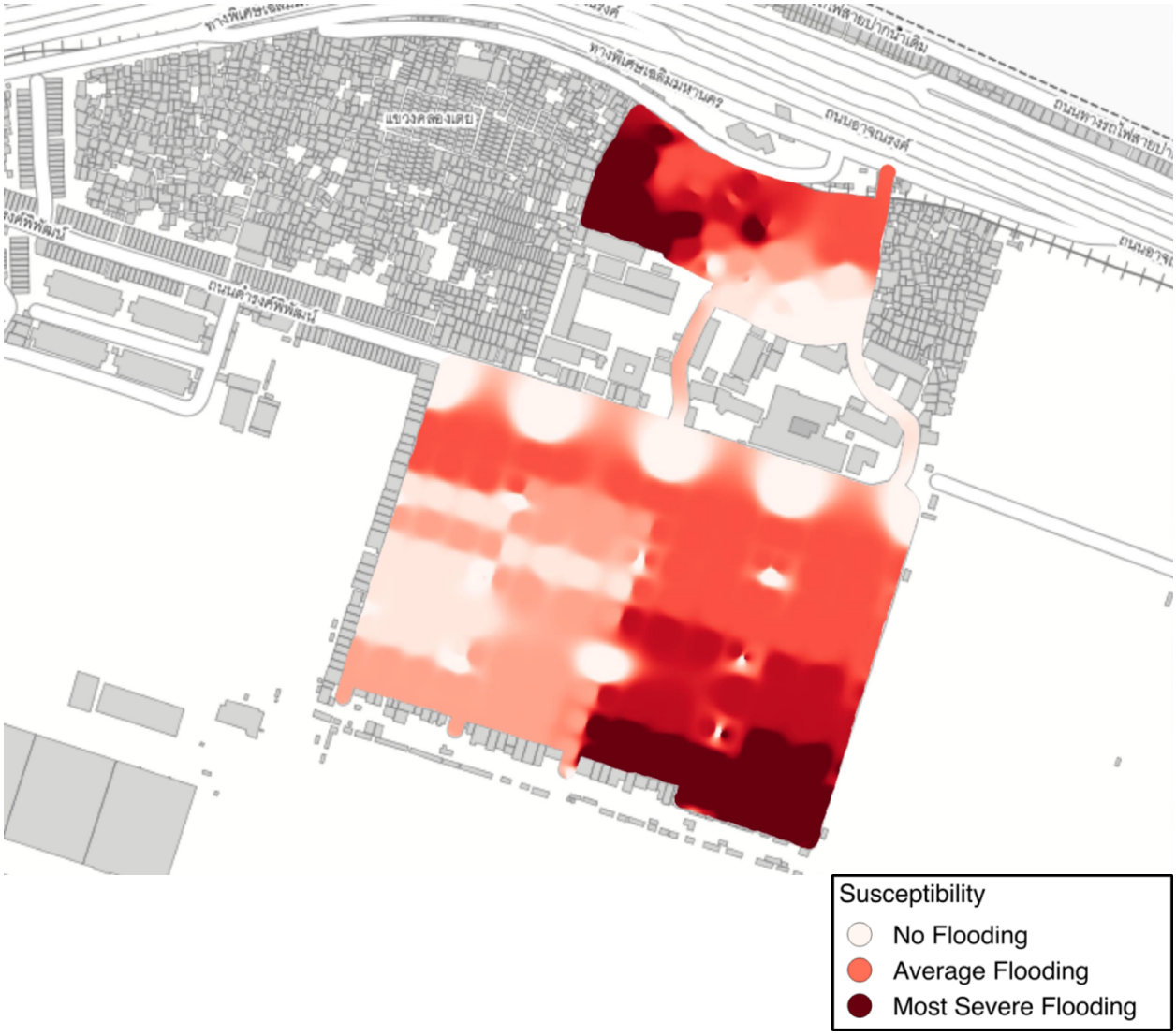
- 45.5 do nothing
- 25 clean drainage themselves
- 13.6 other
- 9.1 pump it out
- 9.1 put cement in front of house
- 4.5 hire someone to clean out the drain

Campaign from trash for cash helped reduce the trash?

- 47.6 yes
- 45.2 no
- 7.1 other

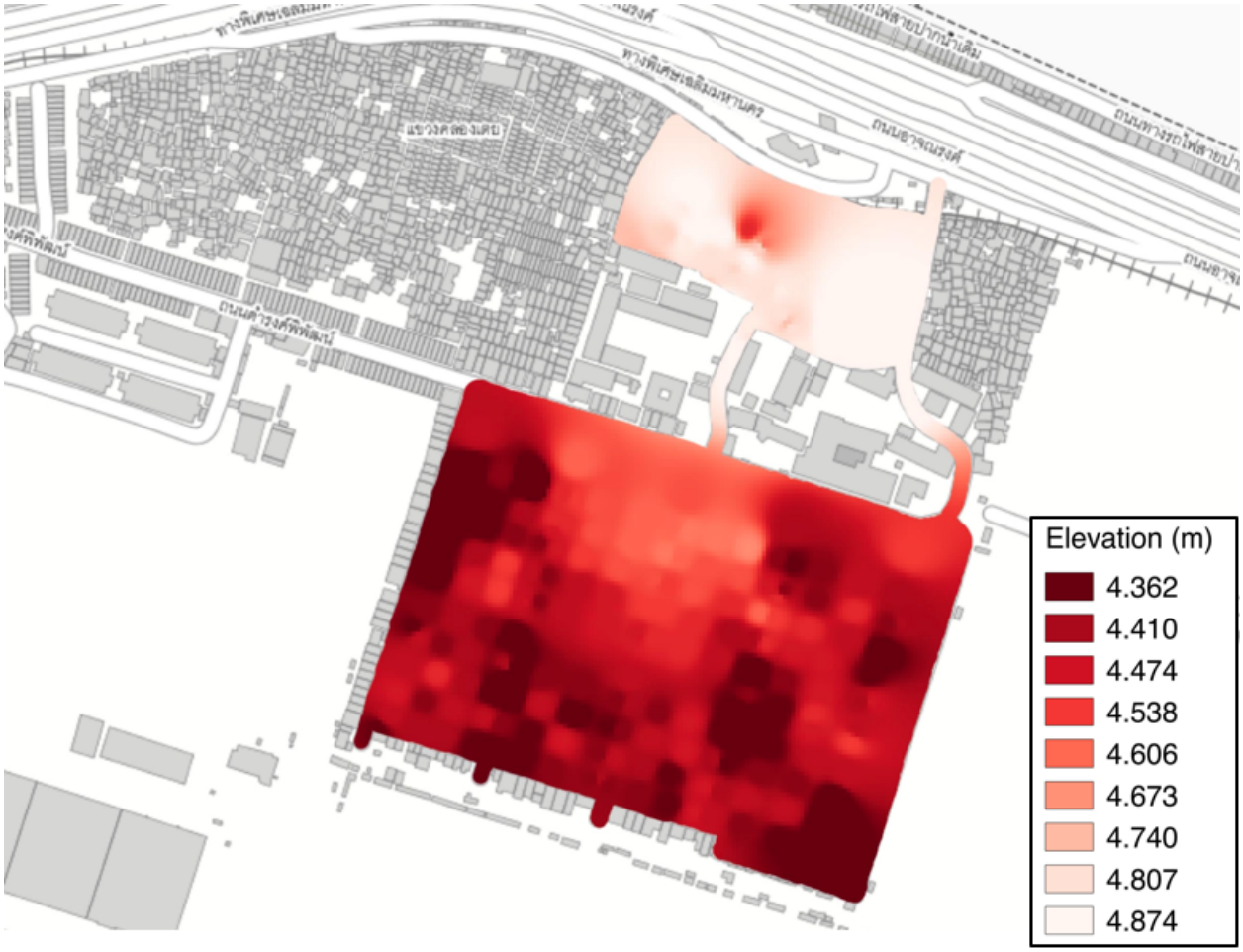
Appendix H: Maps for the Duang Prateep Foundation

Map 1: Susceptibility



This map depicts locations that residents and community leaders have stated are more susceptible to flooding. The darker red represents the areas that are prone to the most severe flooding, while white shows the areas that do not flood. The areas that residents have said are the most vulnerable are the lower right area of 70 Rai, the left side of Lock 4, and the center of Lock 5.

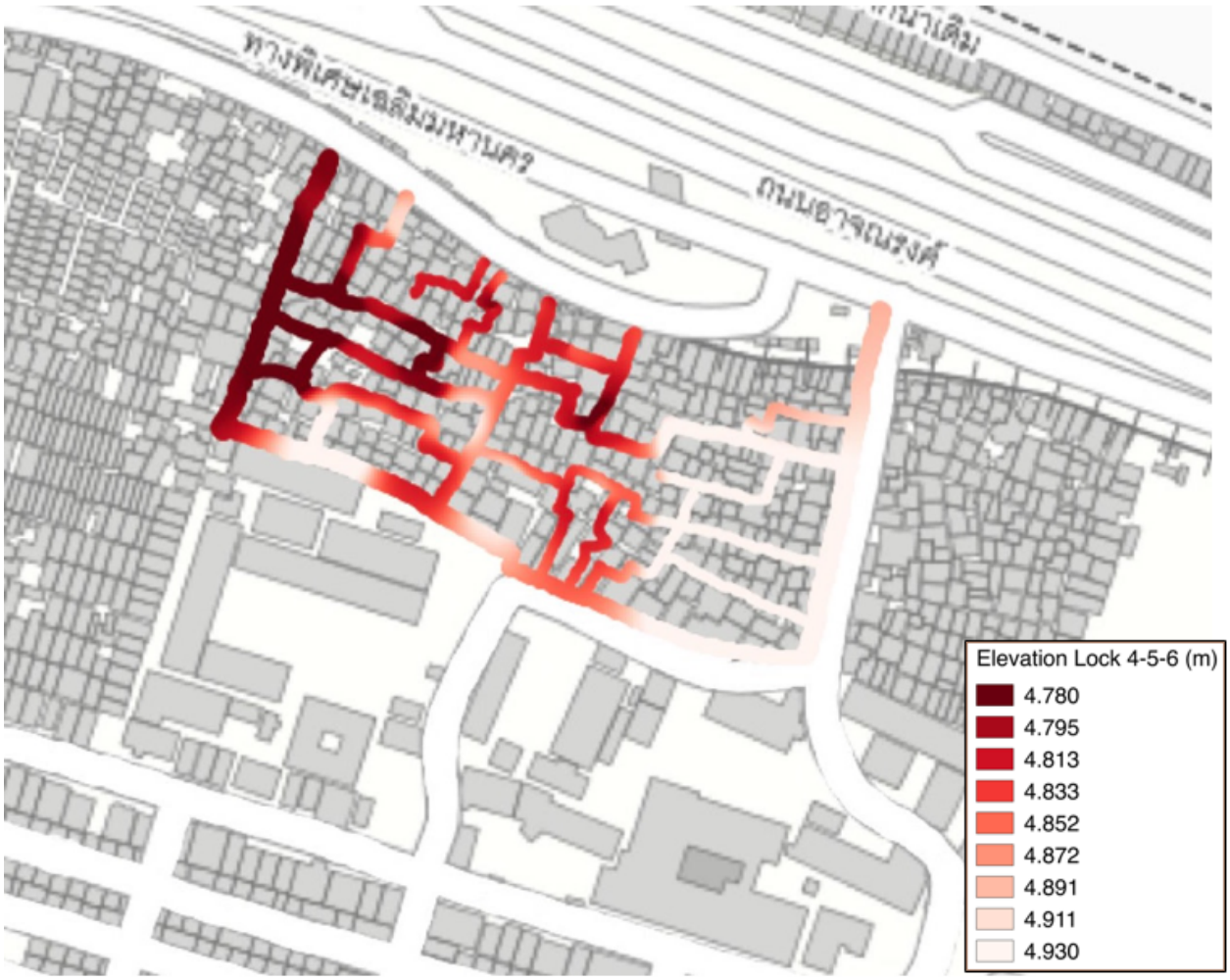
Map 2: Elevation of Lock 4-5-6 and 70 Rai



This map depicts the elevation of Khlong Toei. Elevation data points were gathered at multiple locations along the Sois using the Google Maps Elevation API. Lower lying areas are shown in darker red while the lighter areas are slightly higher. Lock 4-5-6 sits at a higher elevation than 70 Rai. Within 70 Rai, the elevation is higher in the North and lower in the South. The lowest elevation being in the canal located to the south of 70 Rai, towards the Southeast corner of 70 Rai.

The areas that are lower are consistent with where the residents say the flooding is more severe. However, some other areas are low yet do not experience flooding. These reasons are explained further in the report.

Map 3: Elevation of Locks 4-5-6



Map 4: Elevation of 70 Rai

Elevation data gathered from Google Maps API

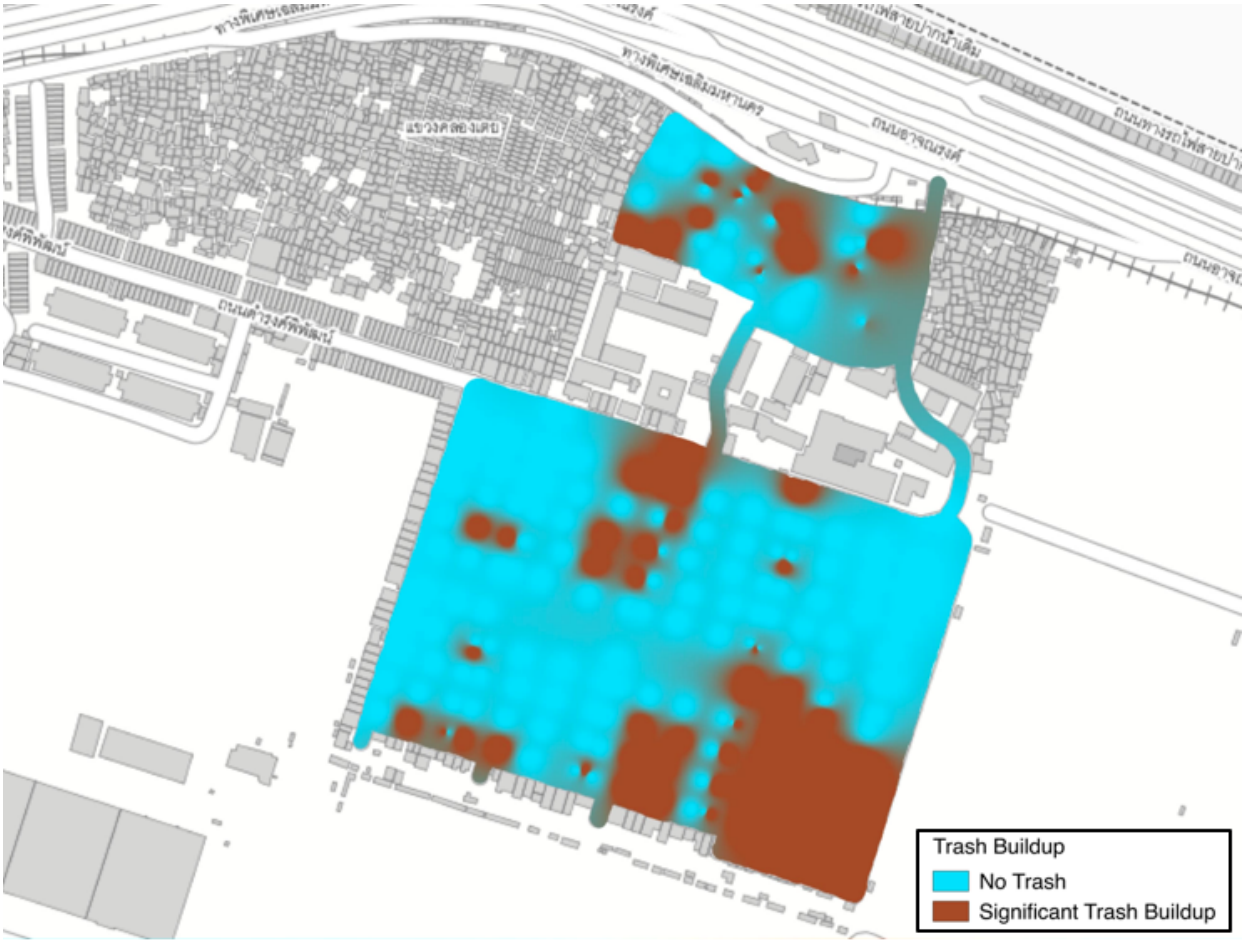
Map 5: Designed Water Flow

This map depicts the flow of water in the drainage system as it was designed. When we compare it to the elevation, it is clear that the system was designed for the water to flow downhill, from the top of 70 Rai to the canal at the bottom where the water is led to the Chao Phraya River through pipes that go underneath the Port Authority.

Map 6: Actual Water Flow

This map depicts the current state of water flow of the drainage system of Khlong Toei. Notice the majority of the drains are stagnant and some portions are flowing in the wrong direction (represented in red arrows). This is the direction of water flow because the canal at the bottom of 70 Rai has nowhere to go, as the pipes leading to the Chao Phraya river that go underneath the Port Authority have been closed off with concrete. Because of this, the community made the drain on the right side of 70 Rai angled so that the water would naturally flow up 70 Rai. This is because the community must pump the water out of the drain to the Hua Lampong Canal, which is at a higher elevation.

Map 7: Trash Buildup

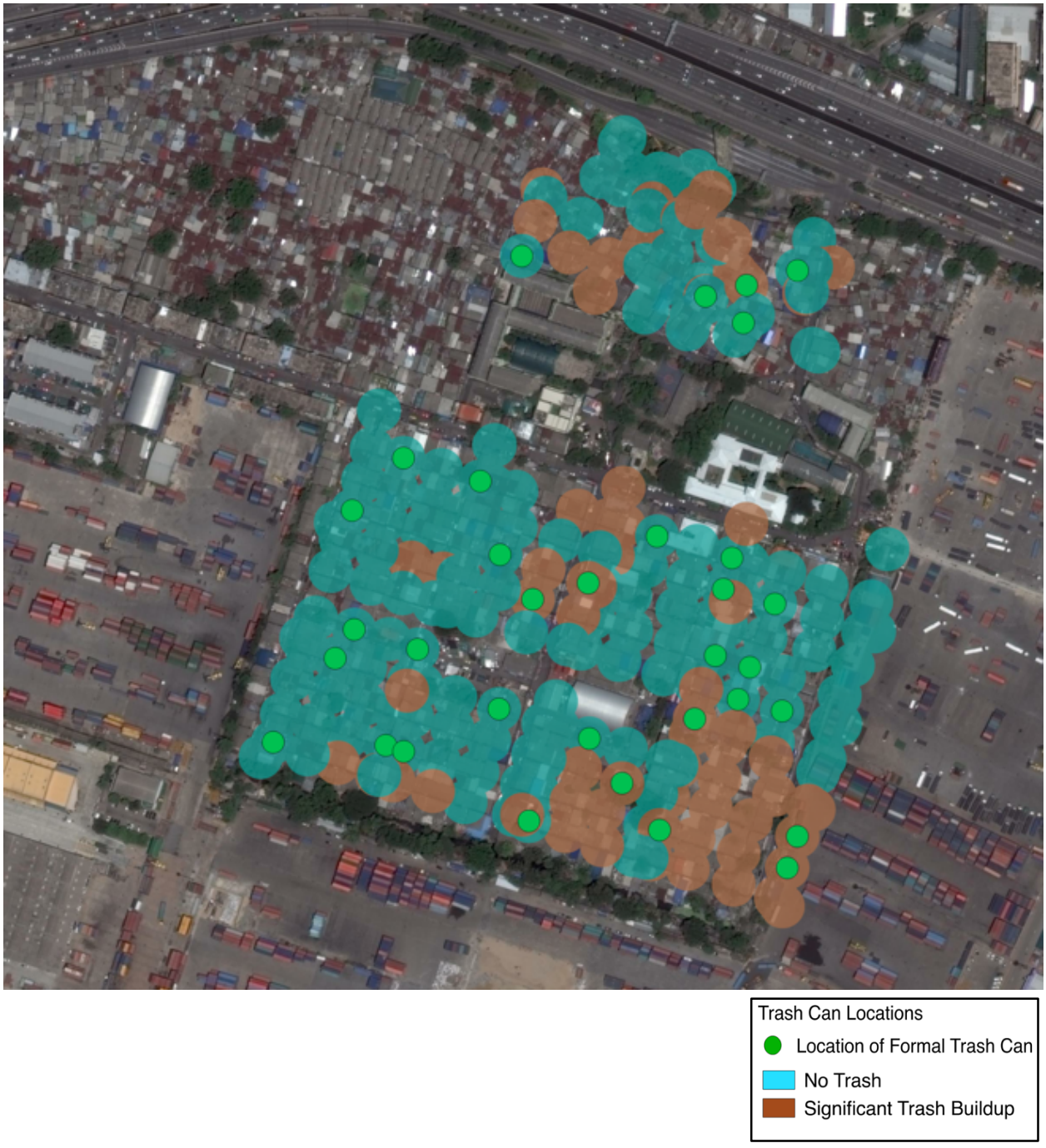


This map depicts locations with excessive trash build up. The area in brown shows where trash has built up in the drains. Notable locations are the bottom right of 70 Rai, the canal in the center of 70 Rai, and the majority of Lock 4-5.

Map 8: Locations of Trash Bins

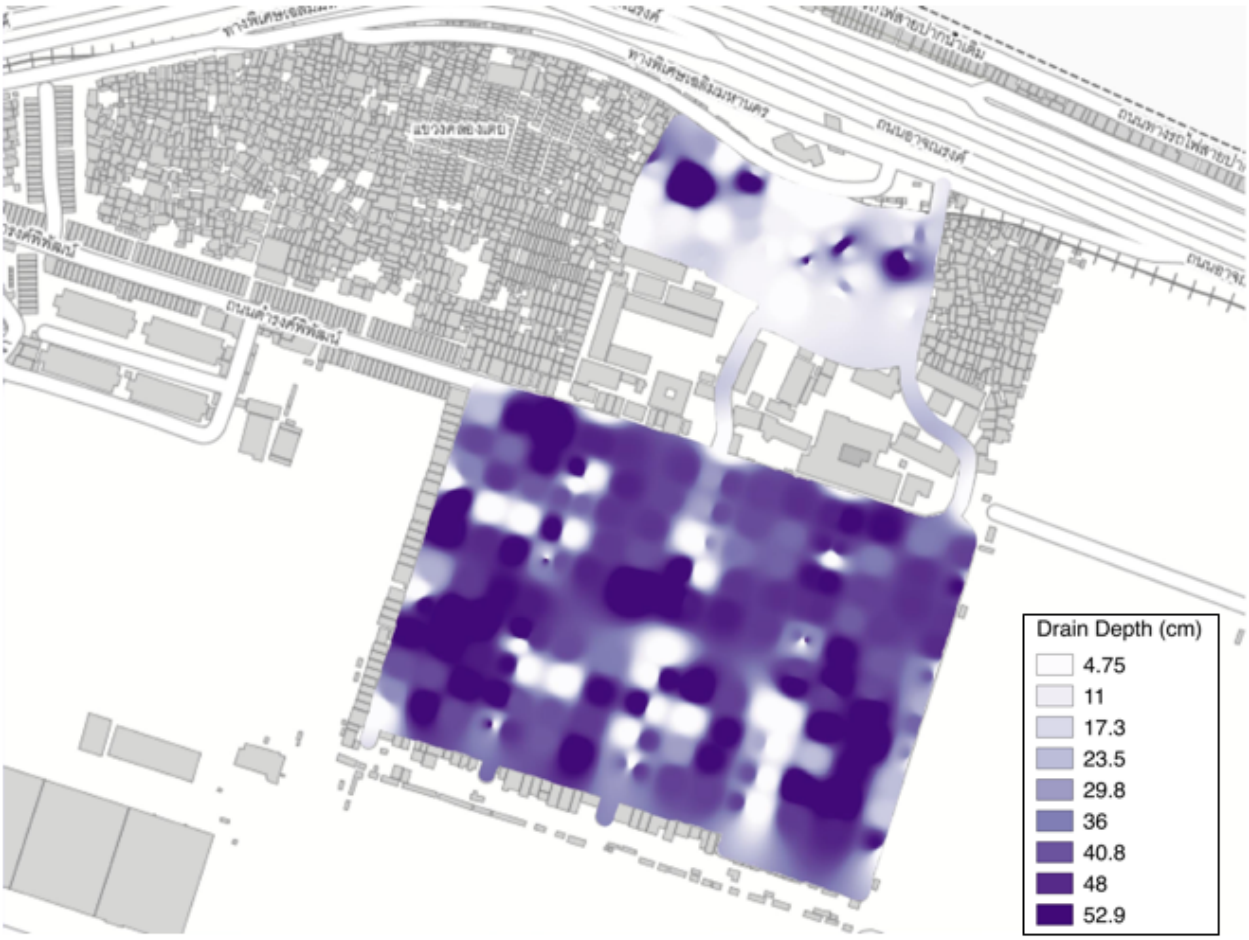
This is the location of the district trash bins we observed. The Khlong Toei District is responsible for emptying these trash bins, which are intended to be picked up daily. There are almost no formal trash bins in Lock 4-5 compared to 70 Rai, where the district trash bins are placed in front of most Sois. The only trash bin in lock 4 is at the lower left area where all of the community trash is collected in a big wasteland.

Map 9: Trash Bins on Trash Buildup



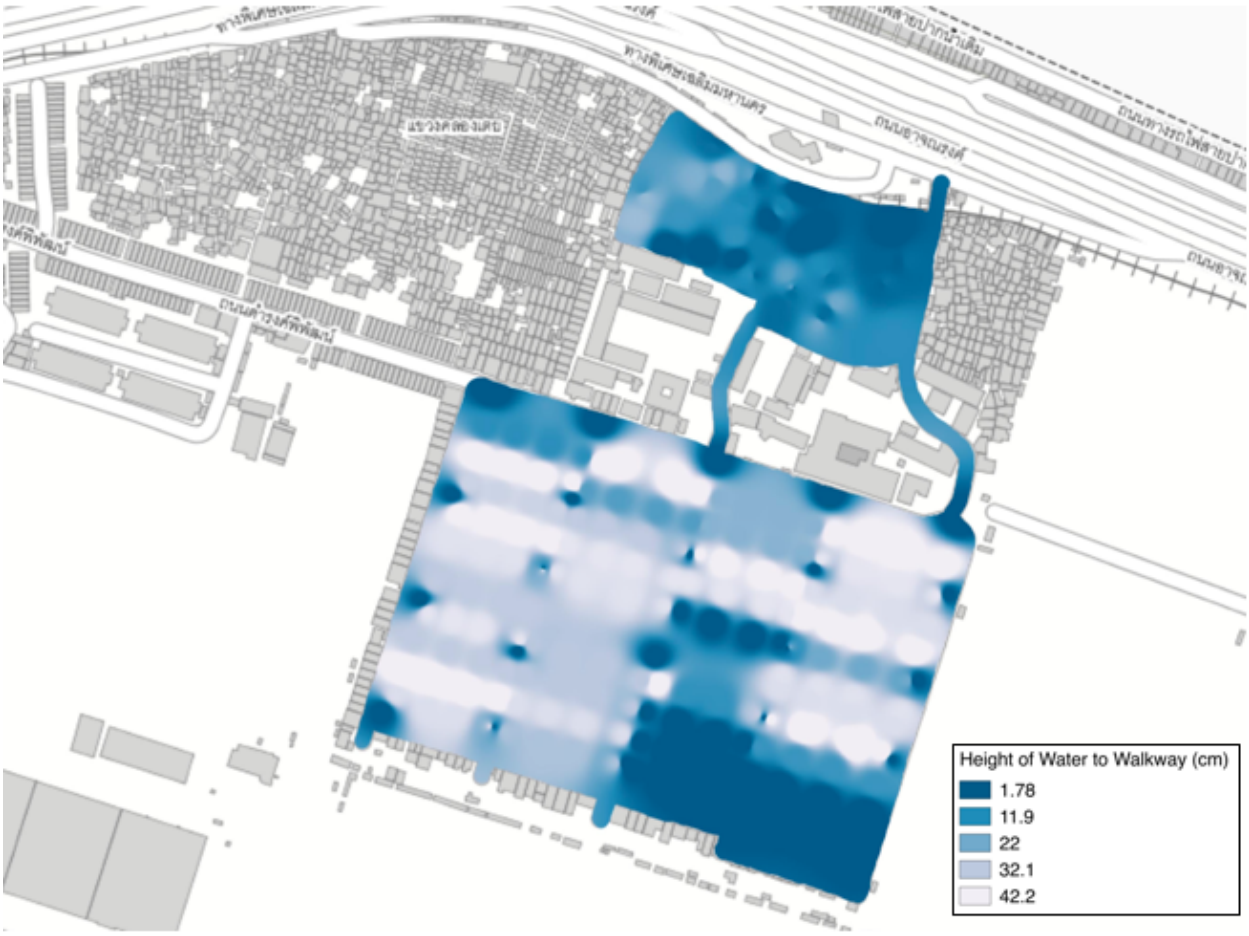
In this map, the locations of the trash bins are overlaid on the areas of trash buildup. The green dots represent the locations of the trash buildup. When we compared this map to the areas of significant trash buildup, we found that the areas that have trash bins are more prone to trash buildup. This is because residents throw their trash into the drain next to the trash bin if the can is full. This simply becomes a trash area, and the waste ends up blocking the drains.

Map 10: Drain Depth



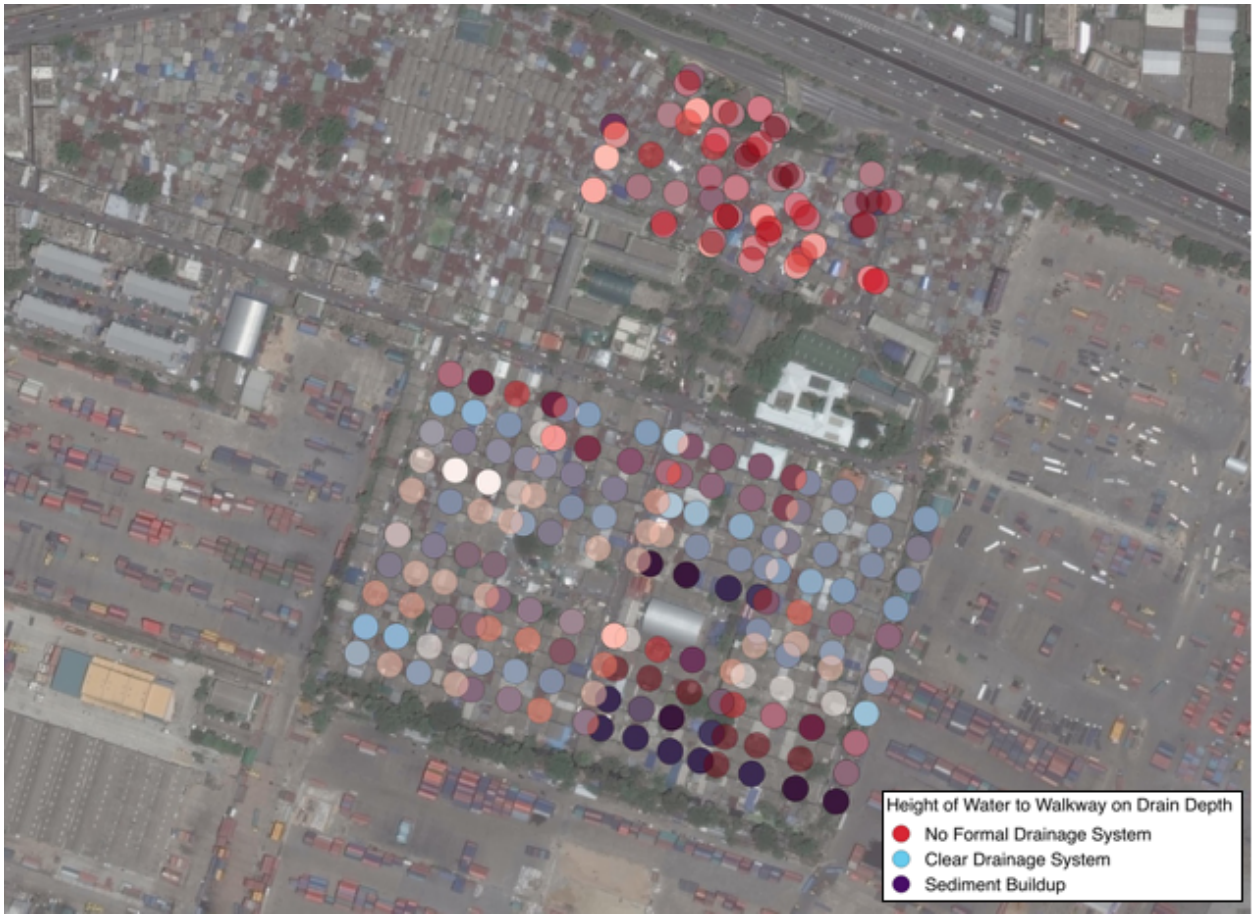
This map shows the depth of the drains in Lock 4-5-6 and 70 Rai. The dark purple represents the deeper drain, while the lighter colors show the shallower drains. When there is no drain then the value for the depth is marked as zero. Locks 4-5 do not have a formal drainage system while 70 Rai does. Any drainage system previously in Lock 4-5 has been covered and blocked by residents filling their land with concrete.

Map 11: Height from the Top of the Water to the Walkway



This map depicts the height of the water in the drains to the walkway on Jan. 26. Lower heights indicate locations that would flood first, as it shows the minimal amount of rainfall before the walkway would be covered in water. Other factors go into this, such as the water flowing from different areas due to elevation, and how effective the drains are for getting the water to flow out of the area. Lower heights may also indicate locations that may have high sediment or trash buildup, potentially going up all the way to the walkway.

Map 12: Height of Water to Walkway on Drain Depth



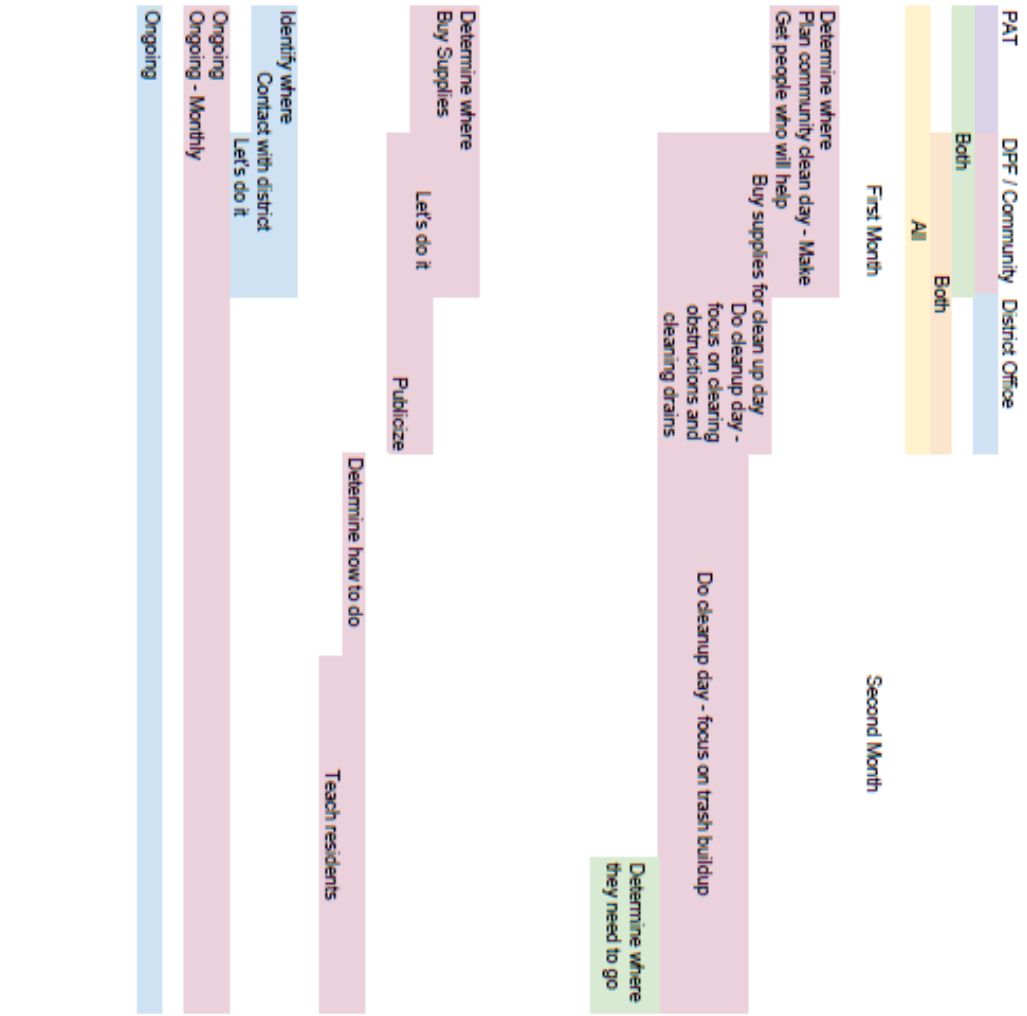
This map shows the height from the water to the walkway overlaid on the depth of the drainage. By making the height of the water to walkway red and partially transparent on top of the drain depth (blue), we can analyze the trends more easily. From this map, we can determine two important findings. First, where there is purple it means that the drain is deep but the water is higher, indicating where there is sediment built up in the drain preventing water from flowing out of the Soi. We can also determine that where there is red means that there is no drainage system, as the drain depth is low, or zero, and the height to walkway is also low.

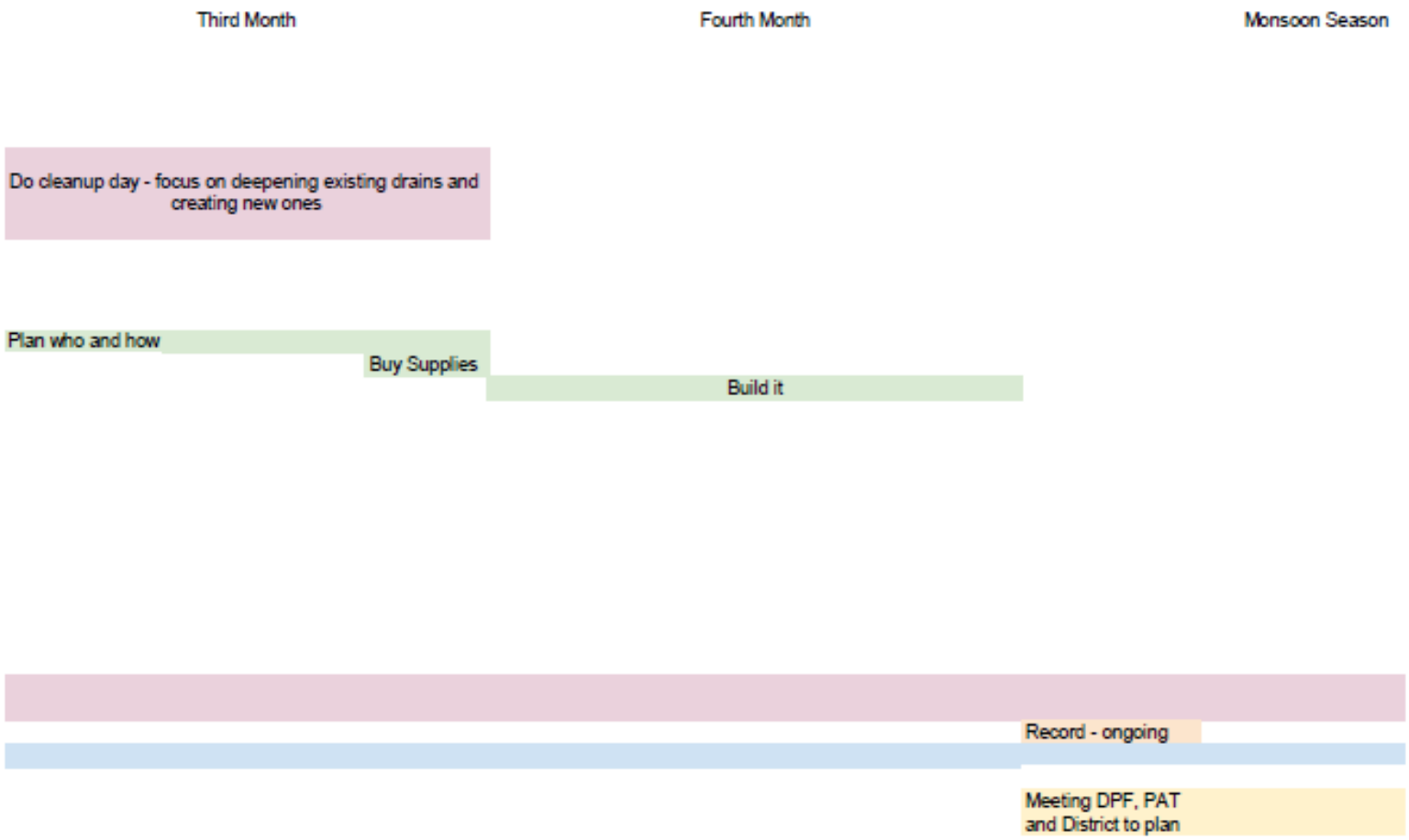
Maps were created by Garrett Holman and Pawitporn Sittapairoj on 13-14 February, 2017 using PhotoScape X and QGIS

Data to create these maps was gathered by the whole IQP/ISSP 6 team

The road map overlaying on maps 1-7 and 10-11 was provided by the DPF

Appendix I: Timeline for the Duang Prateep Foundation

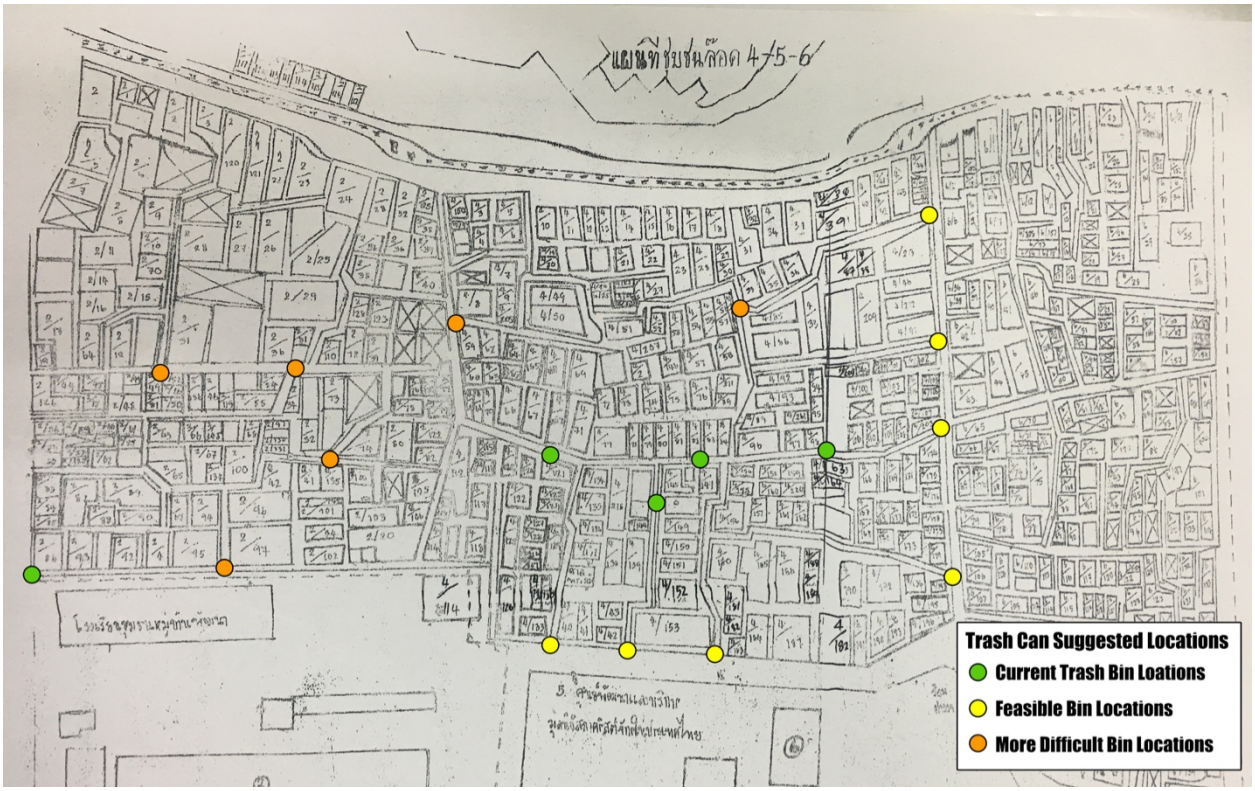



Third Month
Fourth Month
Monsoon Season
Do cleanup day - focus on deepening existing drains and creating new ones
Plan who and how
Buy Supplies
Build it
Record - ongoing
Meeting DPF, PAT and District to plan

Dry Season
Get licensing, get construction contractors
Build it

Appendix J: Maps for Planning Flooding Mitigation

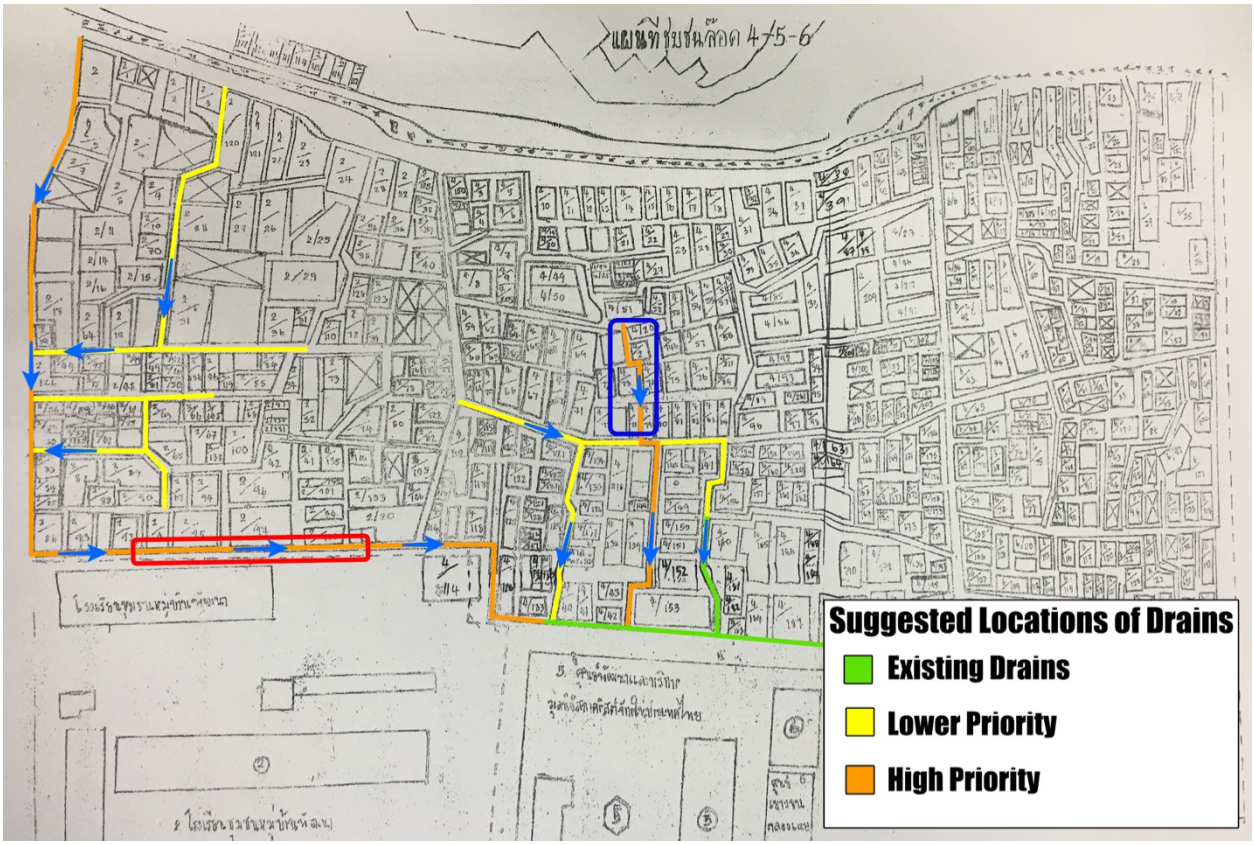
Map 1: Suggested Locations of Trash Bins in Locks 4-5



This is a map of locations for trash bins to be in Lock 4-5. We chose these locations based on the need from areas of trash buildup and susceptibility as well as place that would be easy for workers to pick up. The easiest and most feasible locations are marked in yellow, which are places right next to the main road, easy for workers to empty these bins. The orange markers indicate more difficult bins to put in Locks 4-5, however it is feasible enough then the community could benefit from them.

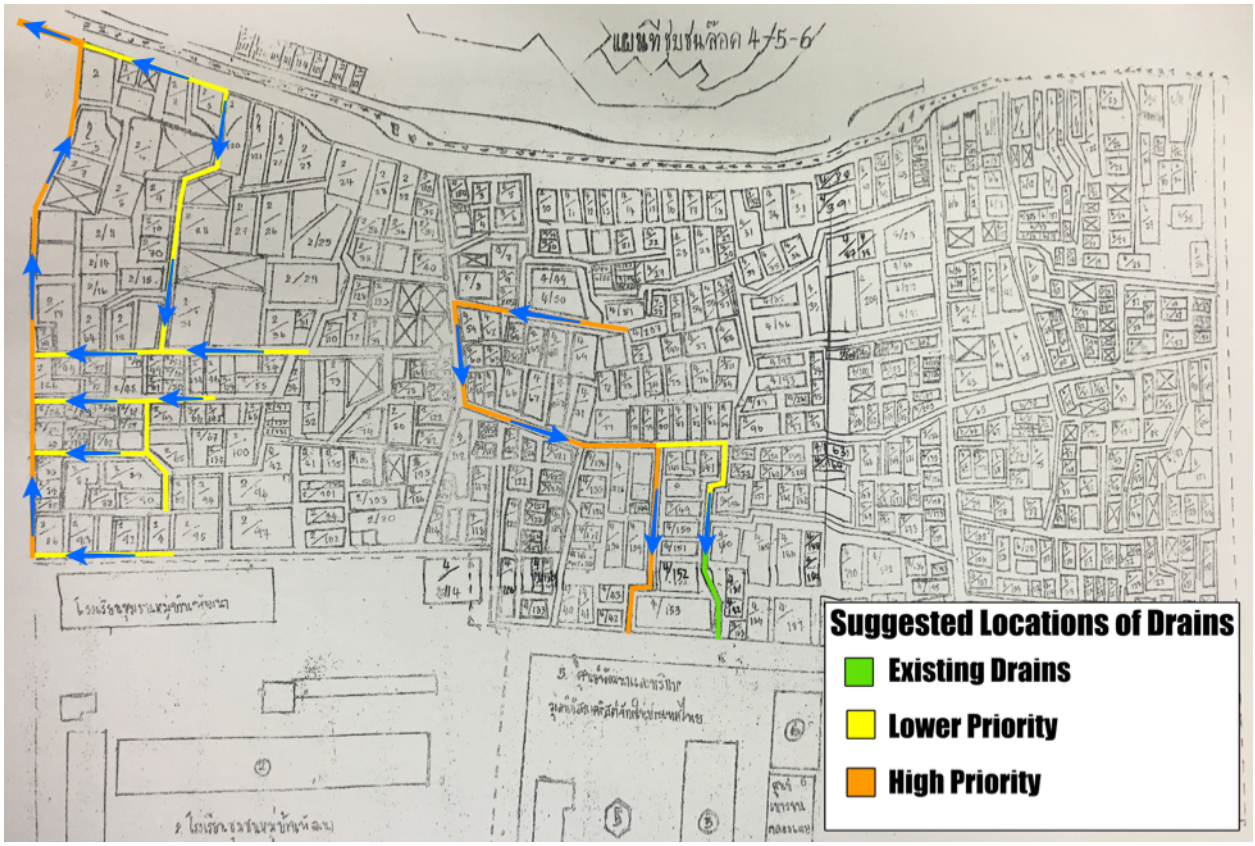
Map 2: Suggested Locations of Drains to be dug in Locks 4-5 #1

Using the maps of elevation and susceptibility, we developed maps that displayed possible options and techniques for mitigating the flooding in the most vulnerable areas in Locks 4-5.



This map shows an option for Sois that could have drains and trenches dug on the side of the road that would be able to allow the water flow out of the areas that are most vulnerable. The blue arrows signify which direction the water would flow. The red box in the Southern part of Lock 4 shows the area where the elevation rises and the drain would have to be planned so that the water does continue to flow down. The blue box in the middle of Lock 5 shows a drain path that would have to be made between housing units. This would be the shorter option and avoids going uphill in the left of the Soi, however requires there to be a drain that goes either between or underneath houses.

Map 3: Suggested Locations of Drains to be dug in Locks 4-5 #2



This map is very similar, but has two major changes from the previous map. On this map, rather than trying to get the water to flow down the right side of Lock 4, if the water were to flow up then it could be connected to the pipe built underneath Lock 1-2-3, leading to the Hua Lampong Canal. In Lock 5, the only difference in this map is that the path for the water to find the underlying cause of Lock 5 follows the Sois rather than cutting between or going underneath houses.

These maps were created using PhotoScape X on road map provided by the DPF by Garrett Holman, Daniel Page, and Justin Trott

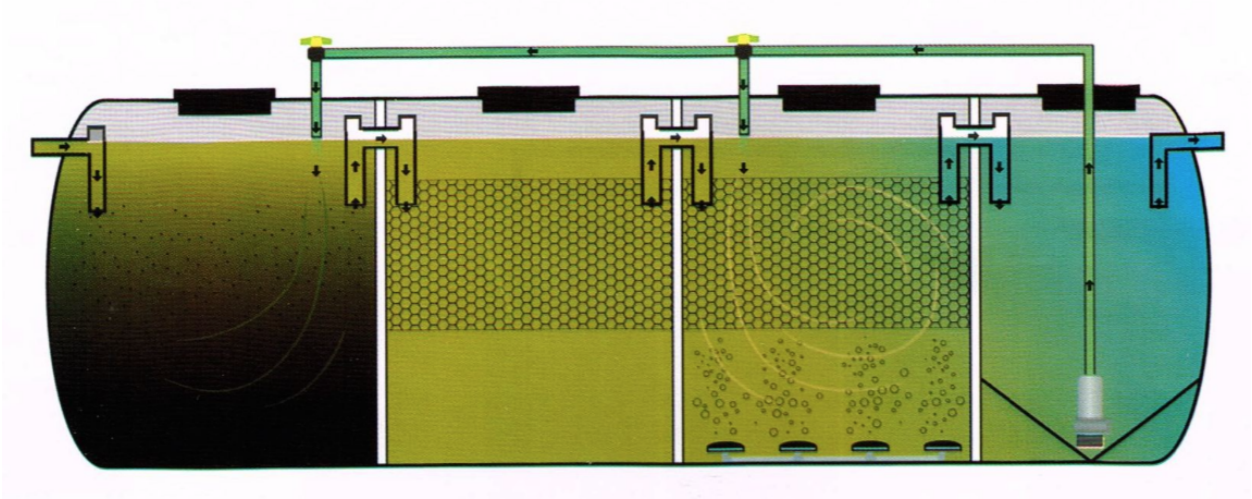
Appendix K: Water Flow

Appendix L: Water Sample Results

	Unit	Result	Standard Value
pH	-	7.5	5.5-9.0
Settleable Solids	Ml/L	0.5	0.5
Total Suspended Solids, **TSS**	mg/L	70.5	30
Total Dissolved Solids, **TDS**	mg/L	348	500
Fat , Oil and Grease	mg/L	3.2	20
Chemical Oxygen Demand, **COD**	mg/L	152	120
Biochemical Oxygen Demand, **BOD**	mg/L	31.7	20
Total Kjeldahl Nitrogen, **TKN**	mg/L	18.6	35
Sulfide	mg/L	1.28	1.0

Appendix M: Water treatment suggestion

The most suitable treatment is the activated sludge system. This system consisting of four parts which are septic, anaerobic, aerobic and sediment. This system can decrease BOD value to lesser than 20 mg/L, the acceptable amount based on the Pollution Control Department of Thailand. The cost for this kind of this treatment is likely to be high. The foundation or the community must propose the plan to the company to appraise the exact price.



http://www.signalsiam.com/index.php?lay=show&ac=article&Id=539377894&Ntype=7

Another alternative is to have a smaller water treatment tank. The price is shown below based on the capacity of the tank. For community like this, we suggest the biggest one at 6,000 L/day and the cost is around 47,800 baht. This type of tank is easy to install and does not take much space.

http://www.signalsiam.com/index.php?lay=show&ac=article&Id=539377894&Ntype=7